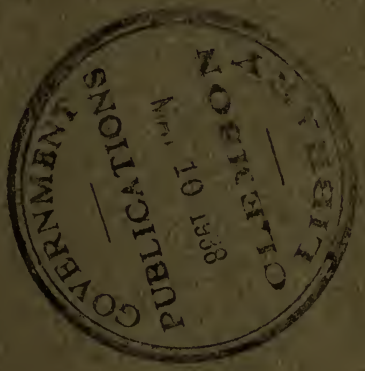
U. S. DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES

PROGRESS IN BIOLOGICAL INQUIRIES 1936

By ELMER HIGGINS

ADMINISTRATIVE REPORT No. 29



U. S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary
BUREAU OF FISHERIES
FRANK T. BELL, Commissioner

Administrative Report No. 29

PROGRESS IN BIOLOGICAL INQUIRIES 1936

By ELMER HIGGINS

APPENDIX III TO REPORT OF COMMISSIONER OF FISHERIES
FOR THE FISCAL YEAR 1937

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ADMINISTRATIVE REPORT SERIES

Since the beginning of the Administrative Report Series, considerable confusion has arisen concerning the system of numbering the separates composing it. Inasmuch as the Reports of the Divisions vary in order from year to year, many have found their designations as "Appendix No. I, II, III, or IV" very confusing. To relieve this, it has been decided to number them as "Administrative Report No. —." Inasmuch as 20 separates had already been printed in this series before starting the numbers, it was deemed advisable to begin the numbering with Administrative Report No. 21. Of course, numbers cannot be printed on those already off the press, but for the information of those who wish to know what the first 25 were, they are numbered for filing purposes as follows:

No. 1. Report, Commissioner of Fisheries, 1931.
No. 2. Alaska Fishery and Fur-Seal Industries, 1930.
No. 3. Fishery Industries of the United States, 1930.
No. 4. Progress in Biological Inquiries, 1930.
No. 5. Propagation and Distribution of Food Fishes, 1931.
No. 6. Report, Commissioner of Fisheries, 1932.
No. 7. Alaska Fishery and Fur-Seal Industries, 1931.
No. 8. Fishery Industries of the United States, 1931.
No. 9. Progress in Biological Inquiries, 1931.
No. 10. Propagation and Distribution of Food Fishes, 1932.
No. 11. Alaska Fishery and Fur-Seal Industries, 1932.
No. 12. Progress in Biological Inquiries, 1932.
No. 13. Fishery Industries of the United States, 1932.
No. 14. Propagation and Distribution of Food Fishes, 1933.
No. 15. Fishery Industries of the United States, 1933.
No. 16. Alaska Fishery and Fur-Seal Industries, 1933.
No. 17. Progress in Biological Inquiries, 1933.
No. 18. Propagation and Distribution of Food Fishes, 1934.
No. 19. Alaska Fishery and Fur-Seal Industries, 1934.
No. 20. Fishery Industries of the United States, 1934.
No. 21. Progress in Biological Inquiries, 1934.
No. 22. Propagation and Distribution of Food Fishes, 1935.
No. 23. Alaska Fishery and Fur-Seal Industries, 1935.
No. 24. Fishery Industries of the United States, 1935.
No. 25. Propagation and Distribution of Food Fishes, 1936.

Note that the last Commissioner's Report was for 1932. Since then its place has been taken by a reprint from the Report of the Secretary of Commerce under the title "Bureau of Fisheries." Inasmuch as it is no longer a Bureau publication, it is not numbered; but it will be supplied to any who request the Report of the Commissioner for any year since 1932.

PROGRESS IN BIOLOGICAL INQUIRIES, 1936[1]

By Elmer Higgins, *Chief, Division of Scientific Inquiry*

[With the collaboration of investigators]

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[1] Administrative Report No. 29, Appendix 3 to Report of the U. S. Commissioner of Fisheries for 1937. Approved for publication Oct. 22, 1937.

INTRODUCTION

The mastery and utilization of the forces of nature depend first of all upon an understanding of natural laws. With such a knowledge these forces can be harnessed, controlled, and directed to economic advantage in some cases or, if they are uncontrollable, human activities can be ordered in accordance therewith. The scientific studies of the Bureau of Fisheries provide a body of facts of permanent value regarding the natural history of fishes upon which commercial and sport fishing depends. Such contributions to our knowledge are therefore permanent contributions to social progress even though opportunities for practical application may not have been realized completely as yet by business enterprise, nor in Governmental organization.

The following illustrations show ways in which these facts are being turned to practical advantage in fishery management. The annual runs of salmon on the Pacific coast and in Alaska are managed by regulating commercial fishing in such a way that ample natural reproduction is assured to sustain the supply and at the same time to provide ever increasing quantities of nutritious food.

Knowledge of the variations in natural reproduction, growth, movements, and local concentrations of the haddock, mackerel, squeteague, and other fishes on the Atlantic and Gulf coasts permits prediction of annual yields of some species to promote orderly and efficient marketing of the catch, directs the way to better utilization of the fish supply through avoiding the waste of immature and unmarketable fish, and demonstrates the necessity of protecting the breeding and nursery grounds of migratory coastal fishes by unified State action throughout the range of the fishery.

A knowledge of the reproduction, growth, and natural requirements of the oyster recently obtained has laid the foundation for a great expansion of oyster farming in our coastal waters that may be relied upon to restore production of this valuable food product to its former high levels when economic conditions permit.

In interior waters, studies of stream pollution have made permanent contribution to the restoration of recreational resources. Through this work an understanding of the effects of domestic sewage, industrial wastes, and other pollutants on aquatic life has been acquired. Future efforts toward the purification of streams and the restoration of angling waters may therefore proceed along intelligently directed lines.

As an outgrowth of these studies there has been developing a definite trend in public thought toward international and interstate cooperation in the conservation of fishery resources.

In the interest of properly administering an extensive program of scientific investigations concerning the fundamental problems of conservation, and application of the knowledge acquired to the problems of practical fishery management, the Division of Scientific Inquiry is organized into eight separate sections each with a responsible experienced fishery biologist in charge who reports direct to the Washington office. Such organization provides a desirable degree of decentralization of administrative control and permits direct attack upon the problems of major importance in each district.

In the field of commercial fishery investigation the North and Middle Atlantic section, with headquarters at the Harvard Biological Laboratories, Cambridge, Mass., is concerned with the marine fisheries of New England and the coastal fisheries of the Middle Atlantic States. The South Atlantic and Gulf section, with headquarters at New Orleans, La., is engaged at the present time in a study of the great shrimp fishery from North Carolina to Texas. The Pacific coast and Alaska section, with headquarters at the United States Fisheries Biological Laboratory, Seattle, Wash., is engaged in a study of the fisheries of the Columbia River, Puget Sound, and Alaska. The Great Lakes section maintains headquarters at the University of Michigan, Ann Arbor, and has been engaged for several years in a comprehensive study of the commercial fisheries of the Great Lakes. These units cover the major regions of the United States where important commercial fisheries are prosecuted, with the exception of the southern Pacific coastal area.

The fields of marine shellfisheries and fishery problems in interior waters are not organized upon a regional basis. The section on marine shellfish investigations is concerned primarily with oyster culture and incidentally with clam culture and related problems. Headquarters are maintained in Washington but field laboratories are established at Milford, Conn., and Beaufort, N. C. Temporary laboratories were maintained at Apalachicola, Fla., and during the early part of the year at Olympia, Wash.

Studies of interior fisheries are conducted by the sections on aquicultural investigations and on investigations in interior waters. The former is concerned primarily with the problems of artificial propagation of fishes and the successful stocking of food and game fishes in streams and lakes. The latter is concerned primarily with the study of pollution in interior waters and with mussel propagation in the Mississippi drainage. Headquarters for aquicultural investigations are maintained in Washington but field activities are conducted at experimental hatcheries at Pittsford, Vt., and Leetown, W. Va. Nutrition studies are conducted in cooperation with Cornell University and the State of New York at Ithaca and Cortland, N. Y. A pathological laboratory is maintained in the fisheries laboratory at Seattle, Wash., and other field studies are conducted at the Bureau's fish-cultural stations, particularly in the Southern States. Investigators in interior waters have excellent laboratory and office facilities at the University of Missouri in Columbia.

The section on ichthyological investigations is housed in the laboratories of the Bureau of Fisheries at Washington, where extensive reference collections of fishes are stored and where the excellent ichthyological collections of the United States National Museum are readily available.

Progress reports of the investigations conducted by the various sections, prepared in the main by the section heads, are given in the following pages.

COOPERATION

In previous reports of the Division of Scientific Inquiry it has been a pleasure to acknowledge extensive cooperation in fishery investigations on the part of many agencies throughout the country. Cordial

cooperation of the same sort has continued during the past year, reflecting in a measure the growing appreciation of the need for more exact knowledge regarding the resource we seek to conserve. Cooperation with various agencies of the Federal Government has been effective; the most outstanding services have been rendered by the United States Forest Service. As a result of a cooperative agreement between the two organizations, the Bureau of Fisheries has assumed responsibility for conducting investigations in forest waters, looking to the perfection of a rational system of stocking and management of supplies of game fishes, improvement of streams to increase productivity, and the regulation of angling. Vested with extensive administrative authority, the Forest Service has actively engaged in stream-improvement construction, preliminary stream surveys, the stocking of forest waters along plans devised by the Bureau of Fisheries, and the regulation of the catch of anglers. Detailed plans for experimental management in various national forests have been developed which materially extend the facilities of this Bureau in acquiring necessary knowledge in this field.

Numerous States have likewise cooperated with the Bureau of Fisheries in investigative work. These include Georgia, Louisiana, and Texas, in connection with the shrimp investigations; Michigan, Ohio, and New York in the collection of detailed statistics for the biological analysis of varying yields of Great Lakes fishes; Connecticut, Virginia, Alabama, and Washington in oyster investigations; and Vermont and California in aquicultural studies. Misisssippi has assisted in an ichthyological survey of its State waters.

Various private agencies have also rendered valuable aid to this Division. Notable among them is the Woods Hole Oceanographic Institution, which has furnished its research vessel *Atlantis* for collections in the offshore New England waters in connection with the study of the haddock and mackerel. Laboratory, office, and library facilities for various sections have been provided by many universities as noted above.

In a somewhat different category from the above type of cooperation, which has included in some cases the furnishing of personnel, boats, laboratory quarters, or services directly concerned with fishery investigations, is the work of the U. S. Corps of Engineers, War Department, which forwarded the study of problems of fish protection at Bonneville Dam on the Columbia River. These studies were originally undertaken by the Bureau of Fisheries under a grant of funds from the War Department, as reviewed in previous annual reports. Because of budgetary limitation, however, it became necessary for the War Department to undertake on its own part the designing of fish protective works and the supervision of their construction. Harlan B. Holmes, Associate Aquatic Biologist of the Bureau of Fisheries, was detailed to the War Department under an extended leave of absence and has been placed in charge of this work. He has conducted the necessary detailed investigations with additional assistants furnished by the Corps of Engineers and reports direct to the District Engineer. The Bureau of Fisheries has maintained close contact with the entire problem, however, reviewing all plans for fish protection and assisting in various other ways with helpful advice and suggestions.

PUBLICATIONS

Owing to the curtailment of funds for printing, the number of publications resulting from investigations of the staff or conducted under the supervision of the Division has been reduced. The list of papers published by the Bureau during 1936 follows:

BIGELOW, HENRY B., and WILLIAM C. SCHROEDER.
Supplemental notes on fishes of the Gulf of Maine. Bulletin No. 20, 24 pp.

DAVIDSON, FREDERICK A., and O. EUGENE SHOSTROM.
Physical and chemical changes in the pink salmon during the spawning migration. Investigational Report No. 33, 37 pp., 15 figs.

DAVIS, H. S.
Care and diseases of trout. Investigational Report No. 35, 76 pp., 15 figs. (Revision of Document No. 1061 and Investigational Report No. 22.)

HERRINGTON, WILLIAM C.
Decline in haddock abundance on Georges Bank and a practical remedy. Fishery Circular No. 23, 22 pp., 15 figs.

HIGGINS, ELMER.
Progress in biological inquiries, 1935. Administrative Report No. 26, 72 pp.

HILE, RALPH.
Age and growth of the cisco *Leucichthys artedi* (LeSueur) in the lakes of the northeastern highlands, Wisconsin. Bulletin No. 19, 107 pp., 11 figs.

HOPKINS, A. E.
Adaptation of the feeding mechanism of the oyster (*Ostrea gigas*) to changes in salinity. Bulletin No. 21, 19 pp., 11 figs.

The following papers were published by members of the staff of the Division of Scientific Inquiry or cooperating investigators during the year 1936 outside of the Bureau of Fisheries series:

AHLSTROM, ELBERT H.
The deep-water plankton of Lake Michigan, exclusive of the crustacea. Transactions, American Microscopical Society, vol. 55, No. 3, pp. 286–299.

BURROWS, R. B.
Parasitism in the starfish. Science, vol. 84, No. 2180, October 9, p. 329.

DAHLGREN, EDWIN H.
Further developments in the tagging of the Pacific herring, *Clupea pallasii*. Journal du Conseil International pour l'Exploration de la Mer, vol. 11, No. 2.
Research shows many herring groups on coast. Annual fisheries edition Ketchikan Chronicle, September 6.

DAVIDSON, FREDERICK A.
How fishing districts are determined. Annual fisheries edition Ketchikan Chronicle, September 6.

DAVIS, H. S.
Steam improvement in national forests. Proceedings, North American Wildlife Conference, pp. 447–453.

EGGLETON, FRANK E.
The deep-water bottom fauna of Lake Michigan. Papers of the Michigan Academy of Science, Arts, and Letters, vol. 21, 1935 (1936), pp. 599–612.
Productivity of the profundal benthic zone in Lake Michigan. Papers of the Michigan Academy of Science, Arts, and Letters, vol. 22, 1936 (1937).

ELLIS, M. M.
Erosion silt as a factor in aquatic environments. Ecology, 17, pp. 29–42.
Effects of pollution on fish. Wyoming Wildlife, vol. 1, No. 8, pp. 15–18.
Effects of pollution on fish. North American Wildlife Conference. Senate Committee Print, 74th Cong., 2d sess., pp. 564–567.
Effects of pollution on fish. Illinois Conservation, vol. 1, No. 4, pp. 10–12.
Some fisheries problems in impounded waters. Transactions American Fisheries Society, vol. 66, pp. 63–71.

ELLIS, M. M. and D. B. CALVIN.
Glycogen content of fresh-water mussels during prolonged starvation. Proceedings of the Society for Experimental Biology and Medicine, vol. 34, pp. 222–225.

FIRTH, F. E.
Gephyroberyx darwinii (Johnson), a berycoid fish new to the North American fauna. Copeia, No. 2 (1936), p. 126.

FIRTH, F. E., and E. W. GUDGER.
Three partially ambicolorate four-spotted flounders, *Paralichthys oblongus*, two each with a hooked dorsal fin and a partially rotated eye. American Museum Novitates, No. 885.

FIRTH, F. E., and J. T. NICHOLS.
A new triacanthid fish and other species from deep water off Virginia. American Museum Novitates, No. 883.

GALTSOFF, PAUL A.
Oil pollution in coastal waters. Proceedings, North American Wildlife Conference, pp. 550–555.

HIGGINS, ELMER.
Research facilities of the U. S. Bureau of Fisheries. Collecting Net, vol. 11, No. 9–10, December, pp. 217 and 252–256.
The importance of conservation. Fishing Gazette, vol. 53, No. 10, p. 13.

HILE, RALPH.
Low production may not mean depletion. The Fisherman, vol. 5, No. 2, pp. 1–2.
Summary of investigations on the morphometry of the cisco, *Leucichthys artedi* (LeSueur), in the lakes of the northeastern highlands, Wisconsin. Papers of the Michigan Academy of Science, Arts, and Letters, vol. 21, pp. 619–634.
Age determination of fish from scales; method and application to fish cultural problems. The Progressive Fish Culturist, No. 23, October, pp. 1–5.
The increase in the abundance of the yellow pike-perch, *Stizostedion vitreum* (Mitchill), in relation to the artificial propagation of the species. Transactions, American Fisheries Society, vol. 66, pp. 143–159.

HILDEBRAND, SAMUEL F.
The tarpon in the Panama Canal. Scientific Monthly, vol. 44, March, pp. 239–248.

HOPKINS, A. E.
Ecological observations on spawning and early larval development in the Olympia oyster (*Ostrea lurida*). Ecology, vol. 17, pp. 551–565.
Pulsating blood vessels in the oyster. Science, vol. 83, June 12, p. 581.
Pulsation of blood vessels in oysters, *Ostrea lurida* and *O. gigas*. Biological Bulletin, vol. 70, pp. 413–425.

LINDNER, MILTON J.
Suggestions for the Louisiana shrimp industry. 12th Biennial Report of the Department of Conservation of the State of Louisiana, pp. 151–167.
Shrimp. Jefferson Parish Yearbook, pp. 31–39.
A discussion of the shrimp trawl-fish problem. Louisiana Conservation Review, vol. 5, No. 4, pp. 12–17 and 51.

LORD, RUSSELL F.
The "test stream" and fish management. Proceedings, North American Wildlife Conference, pp. 317–322.

NEEDHAM, P. R.
Stream improvement in arid regions. Proceedings, North American Wildlife Conference, pp. 453–460.
The Hot Creek rearing ponds. California Fish and Game, vol. 22. pp. 118–125.

SHAPAVALOV, LEO.
Food of the striped bass. California Fish and Game, vol. 22, pp. 261–271.

SURBER, E. W.
Rainbow trout and bottom fauna production in one mile of stream. Transactions, American Fisheries Society, vol. 66, pp. 193–202.

TAFT, A. C.
The Waddell Creek experimental station for trout and salmon studies. California Fish and Game, vol. 22, pp. 99–104.

VAN OOSTEN, JOHN.
A new immigrant comes to Michigan. The Fisherman, vol. 5, No. 6, pp. 1 and 3.
The mortality of fish in Lake Erie. Great Lakes Fisherman, vol. 1, No. 3, August, pp. 2 and 10; No. 4, September, pp. 2–3. Also in Biennial Rept., Board of Fish Commissioners of Pennsylvania, 1937.

VAN OSTEN, JOHN—Continued.
Lake fisheries facing extermination. The Fisherman, vol. 5, No. 11, pp. 1 and 3. (Also under title "Are fisheries facing extermination?" Great Lakes Fisherman, vol. 1, No. 7, December, p. 3.)
The age and growth of the Lake Superior longjaw (*Leucichthys zenithicus* Jordan and Evermann). Papers Michigan Academy of Science, Arts, and Letters, vol. 22.
The Great Lakes fisheries; their proper management for sustained yields. Transactions American Fisheries Society, vol. 66, pp. 131–138.
The dispersal of smelt, *Osmerus mordax* (Mitchill), in the Great Lakes region. Transactions American Fisheries Society, vol. 66, pp. 160–170.
WALFORD, L. A.
Current fishery research in America. Collecting Net, vol. 11, No. 8, August 29.

MULTIGRAPHED PUBLICATIONS

U. S. BUREAU OF FISHERIES (Division of Scientific Inquiry).
The Progressive Fish Culturist. Memorandum I–131, issued monthly.
Fish and Shellfish of the Middle and South Atlantic States. Memorandum I–134–b.
Fish and Shellfish of the Gulf States. Memorandum I–134–c.
VAN OOSTEN, JOHN.
Fishing Industry of the Great Lakes. Memorandum I–63.

NORTH AND MIDDLE ATLANTIC FISHERY INVESTIGATIONS

O. E. SETTE, *in charge*

The upward surge in fish prices and the increased activity in the fishing business which were noted in 1935 continued in 1936, with the result that New England fishery landings reached the highest figure in recent years. Although there was a decline in the landings of several of the staple species such as mackerel, haddock, and cod, this decline was more than offset by increases in the landings of rosefish from 17 to 66.6 million pounds, and in vessel-caught whiting from less than 2 to nearly 18 million pounds. The fishing fleet operated at nearly full capacity throughout the year and experienced its first major expansion since predepression years with the addition of more than a dozen new boats to its numbers. Six of these were large otter trawlers averaging 120 feet in length and 500 horsepower.

The productivity of the various species in general remained satisfactory, although the mackerel catch declined 24 percent from the previous year, owing to a lowered abundance of mackerel as a result of poor survival from the spawning of 1935. However, the catch remained considerably above the average for the present decade.

The haddock fishery on Georges Bank continued to improve from the low level of 1930–31, but remained far below the 1925–29 level. On the Nova Scotian Banks the average productivity was less than during the preceding year owing to the scarcity of haddock spawned since 1929.

Biological investigations were confined to a few of the more important New England and Middle Atlantic fisheries problems. Many others could not be covered because of limited personnel and facilities. Among these was rosefish, which has reached the proportions of a major fishery and about which little is known. The cod population has been subject to increasing exploitation as the haddock supply has diminished, but it is not known what effect the increased strain has had upon its abundance. The yield of flounders has de-

creased considerably during the past decade in spite of the increased utilization of species formerly discarded as trash. Neither the cause of the decline nor the effectiveness of restrictive flounder-fishing legislation in force in some States is known. The fishery for whiting has experienced a great expansion in the past year, giving rise to considerable controversy between trap fishermen and vessel fishermen over the question of whether the increased exploitation is endangering the resource. In this, as in other similar cases, no recommendations could be made owing to the lack of knowledge of the distribution and biology of the species.

Although excellent progress was made during the year in the investigation of the several species receiving special study, certain phases were either entirely neglected or only superficially covered owing to lack of personnel or facilities for work at sea. The mackerel work needs hydrographic and plankton observations to further unravel the mystery of spawning failures so as to foresee the crop of yearling mackerel. The haddock work also requires facilities for deep-sea otter trawling and assistants for tagging and clerical work to extend the catch analysis to supplementary species such as cod and pollock and thus determine what effect their greater exploitation has on the catch of haddock.

The improved method of reporting the landings of the New England vessel fishery, placed in operation at the beginning of 1936, has already demonstrated its value through the enhanced usefulness of the catch records to the biological study of the fisheries. This method was worked out in conjunction with the Division of Fishery Industries and was designed to provide an accurate record of the catch from each fishing area. The areas used were delineated in cooperation with members of the North American Council on Fishery Investigations and it is hoped that eventually the statistics of the various countries will be reported according to this uniform scheme of statistical areas.

Another interesting development during the past year was the exploratory shrimp trawling in the Gulf of Maine. The first cruises were sponsored by Prof. Johan Hjort of Norway and the Woods Hole Oceanographic Institution. After the early work on the *Atlantis* had demonstrated the presence of the shrimp *Pandalus borealis* in considerable quantities, two organizations, Federated Fishing Boats of New England and New York, Inc. and Fisherman's Relief Corporation of Portland, Me., supplied the boat and funds for further exploration. Results indicate that this species may be sufficiently abundant to support a small-boat fishery during certain seasons of the year.

Works Progress Administration Project No. 65–14–1833, begun in June 1936, was continued through the year under the supervision of Messrs. Sette, Herrington, and Nesbit. This project included the compilation of published statistics of New England fisheries, tabulation and analysis of statistical records of the haddock, mackerel, and shore fisheries, and the mounting of an extensive series of haddock, cod, and weakfish scales using the recently developed celluloid impression method.

The headquarters of the North Atlantic staff has remained in the Harvard Biological Laboratories where Harvard University has gen-

erously provided space and facilities for the work. The cooperation of the Woods Hole Oceanographic Institution is gratefully acknowledged, especially the assignment of the research vessel *Atlantis* for haddock trawling cruises, and the personal advice and interest of Prof. Henry B. Bigelow. The assistance and cooperation of fishermen and fish dealers in permitting the use of their records and in other ways is also acknowledged with pleasure.

HADDOCK

The great New England otter-trawl fishery, a development of the past two decades, has depended to a large extent on the extensive haddock populations found on Georges and the Nova Scotian Banks. The increasing catch of haddock roughly paralleled the increase in the number of boats until 1929, when the total catch began to decline despite the increased fishing effort. In the fall of 1930 the Bureau inaugurated an investigation of the haddock fishery to determine the basic causes for the declining catch. The program of investigation was designed to obtain an accurate measure of the extent and cause of changes in the abundance of haddock and to develop a practical plan of management that would maintain the fishery at maximum productiveness.

Owing to the extent and variability of the fishery, the objectives required the establishment of a long-period program of observation and study. This program has produced results that are encouraging although progress has been slow because of limited personnel and facilities for work at sea. It has now been shown that the haddock populations on the New England and Nova Scotian Banks are subject to wide fluctuations in abundance not only from year to year, but to an even greater extent over periods of years. Since 1922 the greatest increase in abundance in successive years (as shown by average catch per unit of fishing effort) was about 40 percent, while the greatest decrease was between 40 and 50 percent. However, over a period of years the range of variation has been much greater, with increases running as high as 220 percent and decreases to the extent of 80 percent. Furthermore, analysis shows that since 1914 there have been two long-period cycles in haddock abundance on Georges Bank and adjacent areas. Minima in the abundance curve occurred during 1914–16, 1923, and 1930–31; while maxima appeared during 1918–19 and 1927. Since 1931, there has been a third upswing which by 1936 had increased the apparent abundance of marketable fish to nearly twice the 1931 minimum. Even with this increase, however, the present peak still is little more than one-third as high as the previous peak in 1927.

The direct cause of both long- and short-period fluctuations in abundance appears to be the success of year-class survival; i. e., the number of young of any single brood which reach commercial size during any year or period of years. It has been demonstrated that since 1923, when the records first began listing scrod haddock (1½- to 2½-pound fish) separately, increases in the level of abundance invariably have been accompanied or immediately preceded by increases in the catch of scrod; while decreases in the level of abundance have been accompanied or preceded by decreases in the scrod

catch. For example, the very poor fishing in 1930–31 was preceded by 3 years of very low scrod catches.

The commercial fishery does not appear to be the basic factor in fluctuations; it serves rather to accelerate the mortality rate and thereby to rapidly decimate a year class once it has reached a size that can be captured by the commercial otter trawls. Such a condition obtained during the 1924–29 period, when the annual landings from Georges Bank increased from 70 to about 220 million pounds. This intensive fishery, combined with a series of poor spawning seasons from 1926 to 1928, resulted in a precipitous decline from peak abundance in 1927 to the low point reached in 1931. Since 1931 there has been a gradual improvement on Georges Bank, due to the relatively successful spawning seasons in 1929, 1931, 1932, 1933, and 1934, and to the fact that the commercial fishery on Georges Bank has been much reduced, averaging for 1932–36 about 72 million pounds, compared to 170 million for the 1927–31 period.

The Nova Scotian Banks (Area XXI) remain the least understood of our major fishing grounds. Practically nothing is known about the distribution or abundance of young haddock below commercial size in this area. There appear to be considerable differences between the populations in the eastern (Banquereau), central (Sable Island and Emerald), and western (Browns) parts of the area, at least for the scrod sizes. Variations in abundance of the Browns Bank population appear to be determined by different factors from those that control the population about Sable Island. For instance, in 1933 when scrod became so abundant in the latter region, they were found in but moderate numbers on Browns Bank. Later, in 1935–36, the average catch per unit of effort of all haddock gradually declined in the Sable Island region while on Browns Bank it experienced a marked increase.

Area XXI was not extensively fished by the New England otter-trawl fleet until 1933 and 1934 when the abundant year class of 1929 reached commercial size and caused an eightfold increase in the scrod catch. In 1935 and 1936 the scrod catch rapidly declined, while the catch of large haddock increased 70 percent as the 1929 class grew from scrod to large haddock. The rapid decline in the scrod catch indicates that the year classes of 1930, 1931, and 1932 were all poor or failures in this area, in contrast to Georges Bank where the classes of 1931 and 1932 were relatively abundant.

Observations and study of the fishery were continued during 1936 under the direction of W. C. Herrington assisted by J. R. Webster and H. M. Bearse. Field observations consisted of work on the Boston Fish Pier and one trawling trip on the *Atlantis* in April to Georges Bank, South Channel, and the southwestern part of Browns Bank. The Fish Pier detail was covered principally by H. M. Bearse who obtained data providing an accurate record of fishing time, position, and other relevant information on all groundfish trips landed at that port, as well as length and scale samples from the haddock catches. Observations include 2,900 interviews, 87,000 length measurements, and 3,339 scale samples. The *Atlantis* trawling trip was made to obtain material for the study of abundance, distribution, and growth of 1-, 2-, and 3-year-old haddock which are below marketable size and cannot be obtained from the commercial catch. On this trip 107 hauls

were made, distributed over the area from South Channel to Browns Bank, and extensive haddock material was obtained, consisting of 5,654 length measurements, 3,358 scale samples, samples of stomach contents, and other data. In addition, considerable material was obtained on other species, and water temperatures for surface, bottom, and intermediate depths were recorded for all stations.

The *Atlantis* trip provided excellent data on the age and distribution of haddock in the Georges Bank region as well as more limited material for the southern part of Browns Bank. In the former area the largest numbers of haddock of commercial sizes (3-year fish and older) were found on central and northeastern Georges; 2-year fish were most abundant on the central part; and 1-year fish were found along the eastern and southeastern edge of the bank out to 60 fathoms. As a general rule, 1-year fish occurred in deeper water than the older fish. On the southern part of the bank, 1-year fish averaged 4 cm longer than those on the northeastern part. Material from Browns Bank indicates that this area may be a nursery ground for a considerable population of young fish. Of 910 haddock taken in 12 complete hauls, 52 percent were 1-year, 36 percent were 2-year, and the remainder mainly 3- and 4-year fish. The growth rate was found to be much slower than on Georges Bank. One-year haddock averaged 16.5 cm long compared to 20.7 cm for Georges Bank; 2-year fish, 24.4 cm compared to 36.8 cm; and 3-year fish, 35.2 cm compared to 46.6 cm.

Georges Bank and adjacent areas.—Analysis of the catch records of two groups of commercial trawlers for 1936 showed that the average daily catch per unit of fishing effort on the New England Banks (Area XXII—South, consisting of Georges Bank, South Channel, and Nantucket Shoals) was about 5 percent higher than in 1935, making 1936 the third successive year of the present upward trend. The improvement was due to the highest abundance of scrod in 10 years, which more than offset a slight decline in the abundance of large haddock. The high scrod catch resulted from exceptionally good year classes spawned in 1933 and 1934. In the fall and winter of the year there also was a considerable concentration of fishing activity on schools of small haddock of the 1935 class. These fish were less than 2 years old and averaged about 14 inches in length and 1 pound in weight.

As a result of the improved catches in Area XXII—South and somewhat reduced catches on the Nova Scotian Banks, the shift of fishing activities to the former area continued. Whereas, in 1935, 63 million pounds of haddock (40 percent of the total) came from Area XXII–South, in 1936 75 million pounds (about 53 percent) came from this area. A substantial increase in the total catch of these banks had been predicted in Progress in Biological Inquiries for 1935.

In previous reports it has been stated that the success of the fishery on the New England Banks is dependent on two factors: First, the rate at which the commercial stock declines as the result of catch and natural mortality; and second, the contribution to the commercial stock from the young haddock spawned 3 years earlier. Results from 1936 indicate that for the future the second part must be amended to include haddock spawned 2 years earlier, for during the summer and fall of 1936 a large part of the scrod catch was made up of 1934-class haddock.

It seems probable that the activities of the New England fleet will be concentrated in Area XXII—South to a somewhat greater extent in 1937 than in 1936, resulting in an increase in the first factor, "total mortality." The second factor—contribution of young fish to the commercial stock—will be supplied by the 1934 and 1935 year classes. Results of the *Atlantis* trips in 1935 and 1936 indicate that in Area XXII—South the 1934 class is somewhat less abundant than that of 1933, while the 1935 class is better than that of 1934. Conclusions from the *Atlantis* trips must be used with caution, however, until later evidence from the commercial fishery demonstrates that this relatively limited data constitutes a representative sample of the Georges Bank population.

If, however, we assume that the year-class rating from the *Atlantis* trawling is correct and that the fishing strain will be somewhat greater than in 1936, then on the New England Banks the catch per unit of effort of large haddock should be considerably less in 1937 than in 1936, while the scrod catch should be considerably less during the spring and early summer and equal or greater during the fall and winter of 1937 than during corresponding periods of 1936. Combined, these results will give an average catch of all haddock per unit of effort somewhat lower than in 1936, while, owing to the expected increase in fishing activity, the total landings should be somewhat greater. The validity of these conclusions is, of course, dependent on the valuation given the 1935 year class, which admittedly is subject to some question.

Nova Scotian Banks.—On the Nova Scotian Banks (Area XXI), the average catch per unit of effort declined about 5 percent under the previous year. This decline was characterized by a rapid falling off in the catch of scrod and an increase in that of large haddock. Although the average for 1936 was but 10 percent below the peak year of 1934, there is some evidence to indicate that the actual abundance has declined more drastically. These data have not yet been sufficiently examined to be considered at this time.

As a result of the decline in average yield and shift of fishing effort to the New England Banks and the rosefish fishery, the total haddock catch from Area XXI declined from 91 million pounds in 1935 to 65 million in 1936.

Because of limited material, predictions for the 1937 season for this area can be but tentative. Figures for catch per unit of effort include data from the whole area although more detailed analysis has indicated that the trends in abundance in the eastern and western parts of the area are dissimilar. The catch per unit (omitting Browns and La Have) has been declining around 10 percent annually since 1934. It seems probable that this decline will be continued or accelerated in 1937 unless the 1933 class proves to have been relatively successful in this region. At the present time no data are available on this question. The 1933 class was abundant in Area XXII—South, but so also were those of 1931 and 1932, and neither of the latter were of any importance in Area XXI except possibly on Browns Bank.

Browns Bank apparently must be considered independently from the remainder of Area XXI. Changes in catch per unit in this region do not appear to show any particular correlation with the abundance of scrod, as on the other banks, or with the population changes either

in Area XXII—South or in the remainder of Area XXI. At the present stage there does not appear to be any consistent basis for conclusions as to the 1937 trend on Browns Bank which, however, plays a relatively minor role in the Area XXI fishery. Tentative conclusions are that in 1937 the average catch per unit for Area XXI as a whole will be considerably below that of the previous year, and that this declining catching rate, combined with the resulting decrease in fishing intensity, will produce a considerable decline in haddock landings from this area.

Savings gear.—Recent developments continue to emphasize the importance of measures designed to reduce the destruction of small haddock. To an increasing extent the fishery in Area XXII—South is dependent on the catch of the smaller sizes (scrod) with the result that the trawlers are doing more fishing in areas where young haddock concentrate during the first 3 years. Furthermore, during 1936 there was an increasing trend toward the catching and sale of small haddock down to three-fourths pound and less in weight. In Area XXII—South these fish are less than 2 years old and usually are highly concentrated on certain parts of the bank. Consequently, when an abundant year-class reaches this age, the young fish can be caught up in great numbers. This practice is unfortunate, for should it increase it appears possible that the trawling fleet could nearly wipe out an entire year-class before it reaches an age of 2 years. These small fish bring a very low price on the market owing to their size. If left in the ocean another year, they would average twice as heavy and, belonging to a more valuable market category, would individually be worth nearly four times as much to the fisherman. In 2 years they would treble in weight and have about nine times the value.

Of the various measures designed to decrease the destruction and capture of undersized haddock, the most effective and practical is the establishment of a minimum mesh size for otter trawls. As the result of extensive field experiments in 1931 and 1932, the Bureau of Fisheries recommended that New England operators establish a minimum mesh size of 4¾ inches for use in all otter trawls. These recommendations, together with a full description of the experiments, were published in 1935 in Investigational Report No. 24. Little action resulted notwithstanding the clear evidence in favor of the larger mesh.

A nontechnical description of the savings gear work and of the importance of saving undersized fish was published in 1936 in Fisheries Circular No. 23. This publication, supplemented by considerable discussion between the Bureau's representatives and the various New England otter-trawl operators, finally resulted in voluntary action on the part of the trawling industry. In November 1936, the Board of Directors of Federated Fishing Boats of New England and New York, Inc., an organization including practically all of the New England operators of large- and medium-sized otter trawlers, unanimously voted that members of the Federation should begin the use of large-meshed otter trawls recommended by the United States Bureau of Fisheries, to begin early in 1937 and continue for a period of 6 months, unless terminated at an earlier date by vote of the Board of Directors. The agreement was to apply to all boats with an overall length of more than 70 feet, catching fish other than rosefish and whiting landed at Maine and Massachusetts ports.

MACKEREL

During 1936 the abundance of mackerel remained at a fairly high level although the total catch, 40,173,400 pounds, represented a decrease of 24 percent as compared with the previous year. This decrease was due to lowered abundance of mackerel in the areas fished by the fleet as a result of poor survival of young from the spawning of 1935. This year-class furnished so few new recruits that they failed to offset more than one-sixth of the losses sustained through the ordinary mortality of the previously existing stock. Though the abundance has been materially lowered, it still remains well above the average for the present decade.

In order to afford opportunity to prepare for publication results of the previous years of mackerel investigations, field work during 1936 was limited to the minimum necessary to provide continuous understanding of current changes in the condition of this resource. As in previous years, this investigation has been under the direction of Oscar E. Sette, who was assisted in the field work by Frank E. Firth. Statistics on the daily landings of each vessel in the fleet were obtained from 12 ports, principally Cape May, N. J., New York, N. Y., New Bedford, Boston, and Gloucester, Mass. Interviews with the fishermen covered 1,017 out of 2,188 fishing trips, and 669 samples were taken from 647 fares landed. The lengths of 44,843 individuals in the samples were recorded and scales were collected from 1,040 mackerel.

Early in the season of 1936 there was issued a prediction of the probable conditions of abundance during the current year. At that time it was evident that the stock of mackerel present in 1935 was such as to provide a 1936 level of abundance 20 percent below that of the previous year. This estimate was exclusive of any mackerel which might be provided by the class of 1935 which was due to make its appearance in the commercial fishery in 1936. Actually the yield of the fishery in 1936, exclusive of the new-year class, was 38,000,000 pounds or within 29 percent of the previous year. The class of 1935 provided 2,000,000 pounds of mackerel, making the net decline 24 percent.

Continuation of research on the natural history and the fluctuations in abundance of the mackerel provided more definite information than has been available heretofore on seasonal movements, location of important spawning grounds, rate of growth during larval, juvenile, and adult existence, fluctuations in annual birth rate (or survival of the young), and the attendant effects on the commercial stock available to the fishery. Continued studies have also provided additional insight into the migratory, spawning, feeding, and schooling habits of the mackerel. Progress has been made in discovering relationship between the southern and northern subdivisions of the stock which have been found to have an important bearing on the availability to our fishermen. These and related subjects are being incorporated in a report intended for publication.

SHORE FISHES OF THE MIDDLE ATLANTIC STATES

Responsible leaders of the fishing industry and of angler organizations recognize that a comprehensive conservation policy is urgently

needed for the Middle Atlantic region. They recognize further that because of the migratory habits of the fish, the division of jurisdiction among many States, and the interstate traffic in the products of the fishery, the problem is far beyond the scope of the conservation organizations of the several States. Commercial fishermen and sportsmen have, therefore, united in urging that the Bureau undertake at once the scientific and economic studies necessary for formulation of a conservation policy designed to correct the evident and increasing depletion of several important species.

The increase in fishing activity in response to improved general economic conditions, and the continued growth of the winter fishery with its attendant additional strain on the stocks of several species, make the situation even more critical. Since several years will be required to complete the necessary investigations, it is urgent that facilities be provided promptly.

Squeteague.—R. A. Nesbit, assisted by W. C. Neville, continued analysis of data collected from 1927 to 1935, inclusive, and brought a comprehensive manuscript on the problems of squeteague conservation nearly to completion. The principal results of the investigation were summarized in Progress in Biological Inquiries for 1935.

Scup.—In 1936 investigation of this species was confined to observations and analysis of landings of the southern winter trawl fishery to determine the yield, the size and age composition of the catch, and the extent of destruction by discarding at sea of small-sized fish. These field observations were made by Frank E. Firth, and the compilation and analysis was, as in former years, continued by William C. Neville. In addition, Mr. Neville made considerable progress on a detailed report on the life history of the species, with special reference to the causes of fluctuations in yield.

The yield of scup of the offshore winter trawl fishery in 1936 rose to a record high level (4,979,000 pounds), and again constituted an important part of the total yield of this fishery, accounting for approximately 26 percent of the total landings of important food fishes (scup, sea bass, croakers, fluke, squeteague). The causes of this increase cannot be definitely stated, for the yield is influenced not only by abundance but by variations from year to year in availability due to changes in hydrography, and by market conditions affecting the amount of fishing effort. In spite of the intensity of the fishery, there is no reason to suspect any decrease in abundance as compared with other recent years. As in the preceding four winters, the landed catch consisted principally of small- and medium-sized scup (¼- to ¾-pound) representing fish 2 to 4 years of age.

Discarding of smaller sizes of scup (7 inches and less) was continued during the winter of 1936. Although accurate information is not available as to the exact quantity, it is believed that considerably fewer of these fish were thrown overboard than in 1934, when the amount of discarding constituted approximately 20 percent by weight and 40 percent by number of the total catch of scup. The discarded scup usually include all of the yearlings and approximately half of the 2-year-olds. Since no observations have been made in the past 4 years in the summer pound-net fishery, where better estimates of the abundance of these sizes can be obtained, it is not known whether the

diminished catch by the 1936 winter fishery of these smaller sizes of scup represents an actual decrease in relative abundance, or lesser availability than in previous winters.

Gear experiments to determine whether or not it is possible to release these small sizes of fish in good condition appear to be necessary despite the relative decrease in this practice during the past winter, since it is known that the smaller sizes of other species, in addition to scup, are being discarded or marketed, probably to the disadvantage of the industry both from the standpoint of conservation and of marketing.

WINTER FLOUNDER

The winter flounder, *Pseudopleuronectes americanus*, plays an important role in salt-water angling in New York and along the southern New England coast. From autumn to late spring when other salt-water game fishes are not present it frequents shallow bays and may be caught from rowboats as well as from more pretentious vessels. It is thus available to many fishermen who cannot afford more expensive transportation.

In response to general complaint of depletion, the Bureau is beginning investigations of the life history and conservation needs of this species. Because of limited funds, the investigation cannot be undertaken on a scale large enough to permit studies over the whole range, and for the present, work must be confined to New York, Connecticut, and Rhode Island.

R. A. Nesbit visited fishing localities in New York to arrange for a tagging experiment in the spring of 1937 and arrangements were made for cooperation with the Rhode Island Division of Fish and Game in tagging experiments in Narragansett Bay.

FISHERY INVESTIGATIONS OF THE SOUTH ATLANTIC AND GULF COASTS

MILTON J. LINDNER, *in charge*

SHRIMP

The shrimp investigations have continued under the direction of Milton J. Lindner, and in cooperation with the Louisiana Department of Conservation, the Texas Game, Fish, and Oyster Commission, and the Georgia Tidewater Department. Laboratory and office space have been furnished by the Louisiana Department of Conservation, the Georgia Tidewater Department, and the San Patricio Canning Co. of Aransas Pass, Tex. The *Pelican*, a 78-foot wooden-hulled Diesel-powered ship, was transferred during the year from the Division of Fish Culture to the Division of Scientific Inquiry for offshore shrimp work in the South Atlantic and Gulf area. Extensive remodeling was necessary to equip the *Pelican* for trawling and hydrographic purposes.

A cooperative program has been arranged with Dr. A. E. Parr of the Bingham Oceanographic Institute and Dr. H. B. Bigelow of the Woods Hole Oceanographic Institute for conducting investigations in the Gulf of Mexico in which the *Pelican* and the research vessel *Atlantis* of the Woods Hole Oceanographic Institute will be operated.

The shrimp fishery is undergoing a stage of continued expansion with the addition of new and improved boats, particularly on the South Atlantic coast. This circumstance is due primarily to the rapid rise in the raw headless shrimp trade. It is a matter of extreme importance that the total catch of shrimp has not increased in proportion to the increase in effort. It appears probable that the shrimp fishery is nearing the limit of productivity under the prevailing fishing methods.

From the present knowledge of the life history of the shrimp we should expect that the first signs of a heavy drain on the fishery would appear during the spring season. The spring fishery is composed of shrimp that have escaped the summer, fall, and winter fisheries, consequently a pronounced reduction of the shrimp population by the fishery during these periods would be evidenced by a scarcity of shrimp the following spring. During the springs of 1935 and 1936 there has been a distinctly noticeable reduction in the take of shrimp throughout the entire commercial range. In both these years the spring fishery was very sporadic and when the runs appeared they were of but short duration.

The trend of the fishery as gathered from the total catch appears to indicate that it will not be possible to materially increase the poundage of shrimp taken under the present methods of operating. Shrimp have a rapid rate of growth, however, and it is highly probable that better protection of the young shrimp would result in a larger annual take.

All attempts to analyze the cycles of abundance have met with little success, as it has been impossible to secure the catch records required for such analysis with the staff and funds available. It is necessary to rely upon the States for securing proper catch statistics, and at present Texas is the only State that is gathering fishery statistics in a manner that will permit their use for abundance analysis. In September 1936, the Texas Game, Fish and Oyster Commission put into effect a new system of collecting fishery statistics which should prove very useful in the future. The daily catches and the locality of fishing are recorded for each boat fishing in Texas waters. It is hoped that more States can be induced to follow this procedure.

Dr. James S. Gutsell, upon completion of a manuscript pertaining to the ovarian development and spawning of the shrimp, was transferred from the shrimp staff in July. Doctor Gutsell found that in the Beaufort, N. C., region the common shrimp in many instances spawn more than once in a spawning season. Definite histological criteria were found for mature and spent ovaries.

Experiments in hatching the planktonic eggs and rearing the larvae of several species of penaeid shrimps, including *Penaeus setiferus*, were conducted at St. Augustine, Fla., during the spring and summer of 1936 by John C. Pearson. Considerable success was obtained in this direction with the result that comprehensive series of the eggs and larvae of four species of Penaeidae are now available for comparison and description. The preparation of a manuscript, including many detailed illustrations of the complicated larval development of the penaeid shrimps, was begun during the past year. Special emphasis is being placed upon the commercial southern shrimps, *Penaeus setiferus* and *Penaeus brasiliensis*.

Although considerable material on the early stages of the commercial shrimps has been obtained during the past 5 years from many areas off the coasts of Louisiana, Florida, and Georgia, it is now evident that future studies on the early life histories must be concentrated in more offshore waters than has hitherto been possible through limited cruising facilities. With recognition characters of the eggs and larvae of at least four species of common littoral penaeid shrimps of our South Atlantic and Gulf coasts now available, analysis of penaeid plankton from offshore areas should be simplified. The availability of offshore plankton seems promised through future activities of the research vessel *Pelican.*

At Aransas Pass, Tex., Kenneth H. Mosher continued the sampling of the commercial catch on a restricted basis. Length measurements and sexual maturity determinations were made on 6,310 shrimp. Of this number 1,715 were from Galveston and the remainder from Aransas Pass. In addition to length measurements, individual weights were recorded on 3,400 shrimp. The weight-length relationship data show that interseasonal differences occur in this relationship.

In the Aransas Pass-Corpus Christi area there occurs during the winter a general disappearance of shrimp from the customary fishing grounds. This winter exodus appears to be associated with temperature. It is highly probable that the movements are offshore rather than coastwise, as the Texas fishery does not show any of the indications of coastal movement that are obvious in the South Atlantic fishery where a coastwise winter migration is known to occur. The length frequency distributions indicate the probability of a return movement to inshore waters in the spring. Before definite reliance can be placed upon the observations, however, a comprehensive tagging program must be undertaken.

During September and early October Mr. Lindner and Mr. Mosher, with the assistance of Mr. Albert Collier of the Texas Game, Fish and Oyster Commission, released approximately 2,500 tagged shrimp in central Texas waters. The Texas Game, Fish and Oyster Commission furnished their laboratory boat *K. T.* for the entire course of the tagging operations. Releases were made in Corpus Christi, Aransas, Copano, San Antonio, Matagorda, and Lavaca Bays. By the end of December the returns on tagged shrimp from Matagorda, Lavaca, San Antonio, and Copano Bays were few, but those from Aransas and Corpus Christi Bays were considerable. More than 10 percent of the total number tagged were returned by December 31 and more than 23 percent of those released in Corpus Christi Bay were recaptured. These returns corroborate the conclusions drawn from the length frequency data that the shrimp move from the bay waters to the waters of the Gulf as the season progresses. A more comprehensive tagging program is planned for the coming year to gain additional information on migrations, growth rate, and fishing intensity.

The tagging program that was initiated along the South Atlantic coast in the fall of 1935 proved to be highly satisfactory and in consequence was extended in 1936 to cover the major portion of the entire South Atlantic fishery. At Cape Canaveral, Fla., and New Smyrna, Fla., 750 tagged shrimp were released during January and February. This central Florida area may be considered the southern

limit of the commercial fishery on the South Atlantic coast. Shrimp are taken in quantities in this region only through the winter months, with January the peak month. The 1935 tagging campaign in Georgia and northern Florida showed that shrimp from the South Carolina, Georgia, and northern Florida area move south to the central Florida coast during the winter.

The releases of tagged shrimp at Cape Canaveral and New Smyrna in January and February 1936 were for the purpose of learning whether there is a return movement to the Georgia coast in the spring, as was indicated by length frequency data. Of 399 releases at Cape Canaveral in January over 41 percent were returned, and the majority of recaptures were made in the vicinity of the Cape within 2 weeks from the date of release. A large proportion of the tagged shrimp undoubtedly succumbed directly or indirectly from the handling received in the tagging process, consequently the above returns indicate that the majority of the successfully tagged shrimp were recaptured near the point of release and in a very short period of time. The numbers of marked individuals that escaped the Cape Canaveral fishery and were recaptured in the northern fishery were insufficient to prove that a return movement to the north occurs in the spring. Nevertheless, the combined evidence of these returns and the length frequency distributions suggest that such a movement may occur. More intensive tagging will be done during the coming winter.

In September Mr. Lindner and Mr. Anderson tagged 3,045 shrimp from Cape Romain, South Carolina, to Brunswick, Ga. The returns indicate that at least a few shrimp from as far north as Cape Romain, S. C., migrate to Florida waters in the winter. The greatest distance between points of release and point of recapture was recorded for a shrimp released near the west end of Bull Creek Island, S. C., on September 6 and recaptured on December 19 off the mouth of Ponce de Leon Inlet, Fla. The distance traveled was well over 300 miles. At the time of tagging this shrimp was 15 cm in length and at recapture had grown to 17 cms.

PACIFIC COAST AND ALASKA FISHERY INVESTIGATIONS

Dr. Frederick A. Davidson, *in charge*

The Pacific coast and Alaska fishery investigations with headquarters in the Bureau of Fisheries Biological Station at Seattle, Wash., are confined mainly to the solution of problems concerning the maintenance and rehabilitation of the salmon and herring fisheries of Alaska and the salmon fisheries of Puget Sound and the Columbia River. All of the major investigations in progress in 1935 were continued in 1936.

COLUMBIA RIVER SALMON FISHERIES

Investigations relative to the maintenance and rehabilitation of the fisheries of the Columbia River were continued during the year 1936 by J. A. Craig, assisted by A. J. Suomela. The major projects of this investigation include:

1. An analysis of the condition and trend of the commercial fishery in the lower estuary of the river to determine whether or not

depletion of the supply is occurring from overfishing, and to establish a basis for proper regulation of the fishery to permit an adequate escapement of adult fish for spawning.

2. A stream survey of the Columbia River system to determine the extent of available spawning areas; to discover barriers to fish migration and to provide for their removal or modification to permit passage of fish; to locate unscreened irrigation outlets; and to determine the productive capacity of the various streams with respect to quantities of fish food and the physical and chemical conditions favoring or hindering the development of young salmon.

3. Research into the history and development of the fisheries of the Columbia and studies of parallel development in other natural resources, such as water power, agriculture. lumbering, and mining, which may have either directly or indirectly influenced the fisheries.

4. Studies of the migrations of salmon by means of tagging experiments.

The collection and analysis of catch records during recent years and currently is being undertaken for comparison with historical records to show the extent to which the fishery resources have declined and the part overfishing may play in reducing the total population. During 1936 a considerable amount of routine work on tabulating the original catch records collected in 1935 was accomplished. The extensive data which include records of the fishery from 1897 to 1935 are now ready for the final analysis which will indicate annual and seasonal fluctuations in abundance of the commercially important species comprising the catch of the Columbia River fisheries. Summaries and tabulations have been completed for the records of chinook, blueback, and silver salmon; and the greater part of the steelhead fishery records have also been summarized. The major portion of the work during 1936 has dealt with fish other than the chinook salmon, because the compilation of catch records for that species was virtually completed in 1935.

The final report on the history and development of the Columbia River fisheries is nearing completion. This study demonstrates the importance and extent of the Indian fishery before the advent of white men on the Columbia and shows the fishing methods employed by the Indians. It also traces the growth of the salmon fishery from its early beginning when explorers and settlers salted a few fish to the great canning industry of the present day. The evolution and operation of each type of gear in use on the Columbia, canning methods, and the development of markets for the finished product have also been investigated.

A tagging experiment was conducted for the purpose of obtaining data concerning the fall run of chinook salmon which passes through the commercial fishery in the Columbia in the latter part of August and during September. The results of this experiment provide data relative to the speed of migration of this run after it enters the river, the minimum distances which the fish travel upstream, the proportion of the run which returns to hatcheries and possibly some measure of the intensity of the commercial fishery above the point of tagging.

This is the second tagging experiment that has been conducted on the fall run of chinooks in the Columbia River. The first was

carried out in 1908 in the same general locality as that of the present experiment. In the earlier work, a total of 59 fish were tagged in a single experiment, of which 25 were chinooks, 16 were silvers, and 18 were steelheads.

The tagging this season consisted of nine experiments carried on from August 16 to September 2, inclusive, in which a total of 1,059 chinooks were tagged and liberated. The experiments were conducted at one location, about 4¾ miles upstream from the mouth of the river.

Of the fish tagged, 220, or 20.8 percent, were recovered. Six, or 0.6 percent, of the recoveries were taken outside the mouth of the river, 5 of which were caught by troll in the vicinity of the Columbia River lightship, while 1 tag was secured from a fish which had migrated north to Willapa Harbor and was taken in the Nasel River by a gill net. A total of 30 tags, or 2.83 percent, were recovered at hatcheries on the Columbia River system. By considering this percentage in relation to the total number of fish entering the hatcheries, it is possible to estimate the total escapement and thus the percentage of the migrants that return to hatcheries. The remainder of the tagged fish were caught in the main Columbia River from near the point of tagging to Celilo Falls, 190 miles upstream. The results of this experiment will be set forth in a report for publication.

Further information on the size and seasonal occurrence of the runs of migratory fish in the upper Columbia River was obtained by means of counting weirs placed in the fish ladders of the Rock Island Dam of the Puget Sound Power & Light Co., located about 14 miles southeast of Wenatchee, Wash. Weirs were placed in all three fishways and men were employed to count the fish passing through at all times that the counting gates were open. A complete count of all fish passing upstream and over the dam was therefore made during the period from May 6, 1936 to September 29, 1936, inclusive. These counts were made as a cooperative effort of the Washington Game Commission, the Washington Fisheries Department, the United States Reclamation Service, and the United States Bureau of Fisheries. During the period of time mentioned above, 7,301 chinook salmon, 16,501 blueback salmon, and 2,374 steelhead trout passed through the ladders. These counts represent the entire run of bluebacks passing Rock Island, because the period of time during which the counting was done included all of the time when bluebacks are present in the river. The total given for chinooks includes the major portion but not all of the run, because some of these fish passed the dam before and after the counts were made. For the same reason it is probably true that the greater part of the steelhead run is not represented in the count. These observations are of value not only because they indicate the dates of the migratory runs in the upper Columbia and furnish an index of the number of each species, but also because they provide important data relating to the problem of fish protection at the Grand Coulee Dam, which is being constructed about 170 miles above the Rock Island Dam.

In order to obtain information on the number of blueback salmon spawning in tributaries of the upper Columbia, weirs were built and counts made of the fish ascending the Wenatchee and Okanogan Riv-

ers. The weir on the Wenatchee River was located at the Tumwater Dam of the Puget Sound Power & Light Co. and was operated from June 16 to September 26, inclusive. During that time, which included the entire duration of the blueback run in the Wenatchee River, 29 blueback salmon, 5 chinook salmon, and 1 steelhead trout were counted. The weir in the Okanogan River was placed at Oroville, Wash., and counts were made from July 9 to October 2. This counting also covered the entire blueback run in that tributary and resulted in the recording of 905 blueback salmon and 4 chinook salmon at the weir. Because of the unusually small size of the Okanogan bluebacks during 1936 and the fact that some of the pickets in the weir were spaced slightly too far apart, some of these fish penetrated the weir and were not counted for a few days' time. Therefore, the actual number of fish passing the weir might have been somewhat more than the total given. These counts not only provide data on the number of bluebacks spawning in the two river systems where the weirs were operated, but also furnish a means of computing the number of bluebacks which normally pass the site of the Grand Coulee Dam. Since there are no other known spawning grounds for bluebacks between Rock Island and Grand Coulee it follows that the difference between the sum of the Wenatchee and Okanogan River bluebacks and the Rock Island bluebacks represents the number which go past Grand Coulee, and which must therefore be provided for in any plan for fish protection in connection with that structure.

Stream survey activities for the season were principally confined within the boundaries of the State of Washington. A total of 743 miles of streams were surveyed during the year. Examinations of the tributary streams of the Columbia in southwestern Washington were undertaken during the fall months. Satisfactory progress was made in the survey in this section. The streams on which surveys have been completed in this area are: Coal Creek, Abernathy Creek, Mill Creek, Skamokawa Creek, Salmon Creek, Lewis River, Tilton River, and Ostrander Creek. Other creeks in southwestern Washington on which additional work must be done to complete the surveys are: Grays River, Alochoman Creek and Kalama River emptying into the main Columbia, and tributaries of the Cowlitz such as Cowieman Creek, Toutle River, and the Cispus River. In the south central area of the State surveys have been completed of Wind River, Rock Creek, and Little White Salmon River. Most of the streams in central Washington had been surveyed previously. The work during the year consisted of surveys of the tributaries of the Yakima River system. The completed surveys are as follows: Teanaway River, Swauk Creek, Taneum Creek, Manastash Creek, Umptanum Creek, and Ahtanum Creek, all of which are tributaries of the main Yakima, and the Little Naches River, Rattlesnake and Cowiche Creeks, tributaries of the Naches River. There remain only 26 miles of survey work for the completion of the main Yakima River. In north central Washington the examination of the Wenatchee River, Entiat River, and Okanogan River systems was finished. The stream surveys in southeastern Washington were completed when Asotin Creek and the Walla Walla River were examined to their headwaters.

PUGET SOUND SALMON FISHERIES

Chief attention during the year has been given to the preparation of a report entitled, "The Salmon and Salmon Fisheries of Swiftsure Bank, Puget Sound and the Fraser River." This report has been prepared to show, in a general way, the history and development of these fisheries, the changes in the various forms of gear, the shifting in intensity and location of the fishing, and the effect that these factors have had on the abundance of the five species of salmon of this region. These fisheries at present yield about 115,000,000 pounds of raw salmon per year, valued at between 10½ and 11½ millions of dollars. The sections dealing with the history and development of the gill-net fishery of the Fraser River, the trap fishery of Puget Sound, and the life history and abundance of the sockeye, pink, and chum salmon were prepared by Dr. George A. Rounsefell. Those dealing with the purse seine and troll fisheries and with the coho and king salmon were prepared by George B. Kelez.

Sockeye.—The Puget Sound sockeye investigation, which is primarily concerned with studies of the causes and extent of the decline in abundance of sockeye salmon in the Puget Sound-Fraser River region, was continued under the direction of Dr. Rounsefell. The commercial catch was again sampled for size and age composition, but owing to the curtailment of the 1936 fishing season by strikes, data from only 1,200 sockeyes in 24 samples were obtained during the period from July 29 to August 31 and no chums could be measured. No pink salmon were sampled, as they are absent from Puget Sound in even-numbered years. Extensive collections of daily catches by traps, purse seines, and gill nets have been made from these data, curves are being constructed for each year to show the seasonal abundance of sockeye in the various forms of gear in each area. When completed, these data will yield valuable information on the routes of migration, the changes in abundance in different portions of the season, and the effect of one form of gear on the catches of another.

Coho.—Coho salmon in Washington have declined markedly in abundance during recent years. Experimental work has therefore been undertaken with the double purpose of providing information relating to rebuilding individual populations through artificial propagation and transplantation of fingerlings, and of furnishing statistical studies of the fishery. Marking experiments have been undertaken with special reference to the success of liberation of hatchery-produced fingerlings of different sizes and to the value of transplanting fish to "foreign" stream systems. These experiments also provide information on the life history of the species. Analyses are being made of the relative contribution of various districts of the region to the commercial fisheries. This work has continued under the direction of Mr. Kelez during the past year.

Returns of adult fish from the Samish River marking experiments appeared this year. In these experiments, conducted in 1934, 26,000 fry hatched at the Samish station in February were marked and liberated in May in Friday Creek, a tributary of the Samish River. Another portion of the Samish fry were held in ponds until November, at which time 26,000 more were marked and liberated.

The comparative returns from these experiments were expected to show whether or not the additional period of pond rearing contributed materially to the resistance of fingerlings to disease and natural enemies. In another experiment, 10,000 fry from the Skykomish station (on an independent stream system) were moved to the Samish station, where they were marked and liberated to determine the effect of such transplantation upon the homing instinct.

Although the returns will not be complete until the cessation of the spawning run in March, 222 marked fish were recovered during 1936. Of these, 6 were from the 26,000 fish liberated in May at a length of approximately 46 mm (1¾ inches), 207 were from the 26,000 fish liberated in November at a length of approximately 102 mm (4 inches), and 9 were from the fish transferred from the Skykomish River and liberated in May at a length of approximately 49 mm (2 inches).

Recoveries were reduced by the loss of the hatchery rack on the Samish River during flood conditions shortly after the run began. This loss could not be repaired for a period of 2 weeks. A number of the marked fish which passed the rack during this time were recovered in Friday Creek, and three others from the tributaries above Friday Creek. Accurate calculations of total returns to the river are thus impossible, but on the basis of recoveries to date, it is evident that the larger Samish fingerlings produced a return approximately 35 times greater than did the smaller ones, and the Skykomish fish, although transplanted from a different river system, produced a return approximately four times better than did the smaller Samish fingerlings.

Collections of scale samples and of length and weight data from the commercial fisheries were continued during the summer fishing season, but were seriously curtailed during the fall season when fishing was interrupted because of price disagreements between fishermen and operators. These data were supplemented by collection from the sport fisheries.

KARLUK RIVER RED SALMON

Studies of the Karluk River red-salmon runs, which were begun in 1921, were continued during 1936 under the direction of J. T. Barnaby. Because it combines the advantages of being situated in the center of a large red-salmon producing area and of having its commercial fishery confined to the vicinity of the river mouth, Karluk River was selected for this long-term study of the ratio between spawning escapement and the return from that escapement, the fluctuations occurring in these ratios from year to year, and the causes for such fluctuations. These studies provide essential information on the number of salmon that should be permitted to escape the commercial fishery in order to provide a spawning reserve sufficient to maintain the fishery at a maximum level of productivity.

A review of returns from the escapements during the period from 1921 to 1928 shows no correction between the size of the escapement and the return; the smallest escapement yielded the largest return per spawning fish (5.6 to 1), while the largest escapement yielded the smallest return (0.6 to 1). To determine what return may be expected from any given escapement, it is necessary to under-

stand the causes of these large fluctuations in the ratios between escapement and return. Recent studies are suggestive of a positive correlation between the growth of migrants during their stay in the lake and the returns from escapements. In reviewing the returns from the escapements from 1921 to 1931, we find that those from the escapements of 1921, 1922, and 1923 were good, those from the next 3 years poor, and those from the following 4 years fair, with an upward trend in the ratio of return to escapement. The small returns from 2 of the 3 years which produced very poor returns were caused, at least in part, by overcrowding on the spawning grounds due to large numbers of fish and relatively dry weather. However, on examining the data of the average length of the seaward migrants resulting from eggs laid in the gravels during the years 1922 to 1933, inclusive, it is quite apparent that there was a downward trend to the average size of the migrants for the first 3 years, that the average size remained constant for the next 4 years, and that there has been an upward trend in the size of the migrants since that time. If such a correlation between growth rate of fingerlings and their survival does exist, we may expect an even larger run of adult reds to the Karluk River in 1937 than was experienced in 1936, when the run amounted to approximately 2,400,000 fish, the largest run to the Karluk River during the past decade. These fish were, for the most part, the progeny from the spawning of 1931 when the escapement amounted to 873,428.

Conditions favorable to the growth of fingerlings while in the lake would be expected to act favorably on their survival and thus to result in an increase in the number of adult fish surviving. Such an expectation is supported by marking experiments which have shown the survival value of the larger seaward migrants to be greater than that of the smaller individuals. Numerous factors affect the growth of the fingerlings, as, for example, their abundance, for in years when the lake contains a large population of fingerlings there is undoubtedly competition for food.

Chemical analyses of the lake and stream waters made during the season were in close agreement with those made during 1935. Phosphorus and silica were the two main limiting factors in the growth of phytoplankton in the lake. The phosphorus and silica brought to the lake by its affluents were taken up during the summer months by the plants as rapidly as they became available. As most of the phosphorus introduced into the lake comes from the bodies of spawning fish, the number of fish in the escapements must have a profound effect on the growth of plankton. Unfortunately, the opportunity for artificially fertilizing a red-salmon lake has never been realized. While at first glance the cost of adequately fertilizing a large lake might appear prohibitive, the resulting increase in its productivity might make such a venture worth while.

Two marking experiments were initiated during the season; 26,700 seaward migrants were marked by the excision of the right ventral and adipose fins and a like number were marked by the amputation of both ventrals and the adipose fin. These experiments, in addition to furnishing information on the survival value of these fish during their stay in the ocean, will furnish data on the relative value of these two marks. In the past it has been considered that they were of equal value, although the assumption has never been tested.

On sampling the run for the presence of fish marked in previous years, 268,000 fish were examined and 1,598 marked fish were found, or approximately 25 percent of the fingerlings marked. The consistently large returns from the marking of Karluk River migrants, which, incidentally, are far greater than have been experienced from other similar marking experiments, fulfill the prediction made by Gilbert and Rich in 1927: "They (the seaward migrants) can well be expected to give a good account of themselves during their life at sea and should escape their enemies in larger measure than do the smaller fingerlings of many other streams." Though the Karluk fingerlings attain their larger size, for the most part, by staying an additional year in fresh water, where they are subject to the depredations of enemies in the lake, they benefit by having a higher survival value during their stay in the ocean.

It has been impossible to determine the mortality rate between the fry stage and the seaward migrant stage owing to the difficulties involved in collecting adequate samples of fingerlings. During this period of their life fingerlings are ordinarily subject to various diseases and parasites, and are preyed upon by their natural enemies, such as trout and birds. Samples of fingerlings collected at Karluk have always been composed of extremely healthy individuals. Birds do not prey to any great extent on the Karluk fingerlings and the stomachs of trout taken in the lake during the past season and previous seasons indicate that the trout feed very sparingly on them, possibly because other forms of food are more easily obtainable. It would appear, therefore, that the habit of spending an extra year in the lake has a salutary effect on the survival value.

PINK SALMON

The activities of the pink-salmon investigation in 1936 as in past years were confined mainly to studies of the pink salmon populations of southeastern Alaska, where the bulk of the pack of this species is made each season. Both the marine and fresh water environments in southeastern Alaska are so varied that they represent practically all the biological conditions that may be found in the habitats of pink salmon throughout the entire range of its distribution, hence it is believed that the fundamental facts secured from the study of the fishery in this section may be applied generally throughout Alaska. A field station is maintained at Little Port Walter on Baranof Island where the greater part of the biological studies are carried on by Dr. F. A. Davidson and S. J. Hutchinson.

The collection of data for racial studies was continued for the purpose of determining the homogeneity or heterogeneity that exists in the various populations in any one season and the racial differences prevalent in the odd- and even-year groups. By operating a counting weir in the stream, a total count of each year's population is made. The fish returning to the stream in 1936 from the 1934 spawning gave the first returns from a known spawning population in this stream. In 1934 the run into the stream consisted of 6,952 pinks, which resulted in the return of 5,164 spawners to the stream in 1936. A study is being made to determine the factors responsible for the inability of the 1934 population to reproduce itself. Of the number passing through the weir, 52 percent were females and 48 percent were

males. A sexing device so constructed that it was possible to observe and record the sex of each individual as it passed through the weir on its way to the spawning grounds showed that males were in excess during the first half of the run, but by the end of the season had reached a normal balance. Egg counts were also made to determine the number of eggs deposited by a female of this season's run. The average number of eggs produced per individual in 1936 was 2,227 eggs. These data furnish a means of determining the year's seeding possibilities in the stream.

A cooperative United States Weather Bureau Station was installed at Little Port Walter during the summer. A number of recording instruments are now in constant operation the year round and furnish a record of the climatic conditions prevailing at the station. Data thus collected will increase the scope of our knowledge regarding weather conditions and their effects upon salmon during the period spent in fresh water. It is known that rainfall directly affects stream conditions during spawning, a shortage of rainfall being detrimental to the eggs producing future populations.

In cooperation with the National Canners Association of Seattle, Wash., a study of the physical and chemical changes that take place within the pink salmon during their period of spawning migration was again carried on at Little Port Walter. A small trap was built and set in the outer bay for the purpose of collecting samples with which to carry out the experiment. A number of salmon were tagged and released from the trap to determine the progress of migration through the bay and into the stream. From those fish taken in the trap and canned for the experiment, a chemical analysis will be made to determine seasonal changes in fat composition and quality of the fish from the opening of the season to the closing date. This information will aid the packers in formulating a standard gage by which salmon may be packed and graded.

Throughout the season a number of samples of fish heads and muscular tissues were taken and preserved for future study. The heads, taken for brain samples which may show changes in the pituitary gland and its effect upon the individual during the onset of sexual maturity, were forwarded for study to Dr. B. M. Allen of the University of California. Tissue samples were taken for the determination of casual factors governing flesh coloration. Color is also being determined in the samples of canned salmon to indicate the color changes in the flesh throughout the season.

A second series of pink-salmon tagging experiments was carried on in the Clarence Strait region of southeastern Alaska in the summer of 1936. On July 18 and 25, and August 1 and 15, 2,000 salmon were tagged from a trap located at McClean Point, about 7 miles north of the south entrance into Clarence Strait. On August 16, 500 salmon were tagged at a trap located at Point Colpoys, which is just outside the north entrance into Clarence Strait. These tagging experiments concluded the 2-year tagging program of consecutive weekly taggings in the Clarence Strait region. By means of this program a detailed analysis has been made of the migratory routes of pink salmon in Clarence Strait and adjacent channels during various times in the migrating season. The results indicate that the pink salmon entering Clarence Strait during the first part of the season are bound for

the spawning grounds farthest removed from the entrances to the Strait, while those entering during the latter part of the season are bound for spawning grounds just beyond the entrances.

The native and exotic distribution of the Pacific salmon has been investigated during the past year and a complete report is being written. This study was originally confined to the pink salmon, but was later extended to include all species of Pacific salmon. Information has been received from virtually every State and country receiving shipments of eggs from 1873 to the present date. The success or failure of plantings to develop sea-run populations is known and charts of the world have been prepared to indicate the range of the native distribution, the foreign localities where the transplants have been successful, and the localities where transplants have failed. Included with this information are data on currents, temperatures, and salinities of the oceans throughout the distributions. Each factor in the native habitat has been compared with those existing in the exotic habitat. It appears that where conditions similar to those found in the native distribution prevail in the exotic distribution, the plantings have usually been successful, but where dissimilar conditions are encountered, the introduction has failed. Hence, in all future distribution of eggs or fry to new environments, the environmental factors in the new habitat should be similar to those within the native range.

ALASKA SALMON STATISTICS

The collection, tabulation, and statistical analysis of all catch statistics of the Alaska salmon fisheries was originated in 1935 and continued in 1936 through a cooperative arrangement between the Alaska Division, the Division of Scientific Inquiry, and the Division of Fishery Industries. Its purposes are several: First, to collect all available records of the daily catch of salmon in Alaska from each form of gear; second, to add to those early records the current data as they become available each year; third, to index and segregate these data by area, species, and type of gear; fourth, to tabulate these data into form for statistical analysis for the study of specific problems. L. S. Christey conducted these activities.

The investigation was continued during 1936 along lines similar to those followed in 1935 and described in Progress in Biological Inquiries, 1935. The current year's data were collected and are in the process of tabulation. The chum-salmon data for all years in southeastern Alaska have been collected. The canvass for records of the Prince William Sound area has been completed, and the data tabulated for two species, the pink and chum salmon. The catch records collected from this district cover only the years from 1917 to date. While there are on hand some records for Cook Inlet covering the period from 1912 to date, a more complete canvass of this area is being made. In addition to the above material, some records have been acquired from other districts. As yet, however, time limitations have precluded a complete systematic survey of these areas.

Plans for the future call for the extension of the survey to the remaining areas, the continued collection of current records, and the completion of the tabulation. It should be emphasized that the collection of these data is of paramount importance not only because of its present value, but because every year sees more of the early

records lost or destroyed. Data which may be urgently needed by some future investigation may at present be readily accessible; when needed, they may be impossible to obtain.

HERRING

The herring investigation, under the direction of E. H. Dahlgren, was again confined to southeastern Alaska, where the most intensive fishing has been carried on. Efforts were made to extend knowledge concerning the various populations which contribute to the fishery, as well as to search for the causes of observed fluctuations in abundance of these populations.

To summarize the findings to date, it has been demonstrated that the stocks of herring which contribute to this fishery, instead of being a homogeneous unit, consist of a series of independent populations, or "races," each with its own limited range. The delineation of the areas frequented by the various races, first, undertaken by the analysis of biometrical measurements on a large number of individuals, has been made more definite by the development of a method of tagging. Early tagging experiments have established the fact that the most important single population on which the fishery draws is that which spawns in the vicinity of Sitka on Baranof Island, with a summer feeding area in the region of Cape Ommaney; that the population of next importance is that which spawns in the vicinity of Craig, on Prince of Wales Island, with its feeding area in the Iphigenia Bay region. It has also been demonstrated that the spawning population from the Juneau area does not contribute to the summer fishery in either of these areas, and that there is considerable intermingling between the Sitka and Craig population in the Iphigenia Bay region.

An extension of the tagging program to include areas for which no data are yet available was undertaken during the year. Failure to locate the spawning herring in areas from which they have been reported as formerly abundant limited the scope of the proposed operations. However, besides tagging 10,784 individuals on the Sitka spawning grounds and 4,880 at Craig in order to obtain further data on the migration and mortality of these two important populations, 5,020 tags were affixed at Rose Inlet, about 50 miles south of Craig, in order to delimit the range of the Craig population, and 9,700 fish were tagged at Auke Bay, in the Juneau spawning area, to obtain information on the migrations of these fish, which comprise one of the major populations of the southeastern district.

The recovery of 1,647 tags during the fishing season leads to the conclusions that: 1, The Sitka population supports the fishery not only of the Cape Ommaney area, but also of the east shore of Baranof Island at least as far north as Red Bluff Bay; 2, the Craig population intermingles with the Sitka population to a greater extent than has hitherto been supposed, not only in the Iphigenia Bay region but also at Cape Ommaney; 3, the two populations of Craig and Sitka, which support the fishery in the Iphigenia Bay region, also appear later in the season in the Tebenkof area on the west coast of Kuiu Island, to support that run. The recovery of tags affixed to the Auke Bay spawners in the Douglas Island fishery proves that this area is dependent on the Juneau spawning area for its support; the

recovery of only a few of these tags from the Icy Strait fishery demonstrated that there is some intermingling between the Juneau spawners and an unknown population which supports this fishery. The failure to recover any of the Juneau tags in the lower Chatham Straits-Iphigenia Bay area confirms the former findings that established the independence of these populations. The failure to recover more than a few tags from the Rose Inlet tagging demonstrated that this population, although it intermingles to a slight extent with that of Craig, contributes no appreciable part to the commercial catch in the areas at present being fished.

A consideration of major importance is the fact that certain factors, in addition to the inroads made on the stocks by man's fishing, influence the abundance of each of the populations whose existence has been demonstrated. Of these factors, the most important appears to be the survival rate of the offspring from a given spawning. The result of particularly propitious spawning conditions is the appearance of a "dominant" year class; that of particularly adverse conditions is a virtual failure of that brood to appear in the catch. All degrees between these two extremes appear. The dominant year classes which result from a successful spawning have been demonstrated to be one of the major causes for the fluctuations in abundance which are observed to occur. The system of bi-weekly samples to show the size and age composition of the catch from the more important fishing areas is therefore maintained to determine the status of the various brood years which make up the stocks of herring. This analysis has disclosed that the Cape Ommaney fishery has been maintained for the past 3 years by the offspring from the 1931 spawning, which entered the catch for the first time as 3-year-olds in 1934, continued to dominate as 4-year-olds in 1935 and as 5-year-olds in 1936. There was evidently a virtual failure of the 1932 and 1933 spawnings. This has led to a relatively low abundance as reflected in a low catch per unit of gear in this area, despite a reduction in the amount of fishing effort. A 6-week closed season was imposed on this area during the year to afford this population the necessary protection.

GREAT LAKES FISHERY INVESTIGATIONS

Dr. John Van Oosten, *in charge*

No field work was conducted on the Great Lakes during the calendar year 1936. This enabled the staff, under the direction of Dr. John Van Oosten, to make excellent progress in the compilation of data collected during earlier investigations in the field. During the year 18 papers dealing with the Great Lakes were written for publication by members of the Great Lakes staff and cooperating associates. The manuscript on the deep-water trap net in relation to the whitefish of Lake Huron and Lake Michigan was completely revised for publication, as was the manuscript entitled, "A Limnological Survey of Western Lake Erie with Special Reference to Pollution."

The Great Lakes staff continued its cordial relations and active cooperation with the various States fronting the Great Lakes, as well as with the fishing industry of these lakes. A large number of memoranda to be used as a basis for uniform fisheries legislation

were drawn up for the Conservation Departments of several States. Special effort has been put forth to introduce the flexible steel rule developed by the National Bureau of Standards and the Bureau of Fisheries for the measurement of mesh in gill nets. It is believed that with the uniform adoption of this flexible rule many of the controversies concerning the size of mesh in gill nets will be definitely settled.

Little progress has been made in the enactment of uniform fishery legislation on the various lakes, although three conferences, at each of which the Bureau was represented, were held during the year with that objective in view. The first of these conferences was held at Chicago, Ill., on January 6–7, 1936, when members of the National Planning Council of Commercial and Game Fish Commissioners of the North Central Zone discussed the adoption of uniform laws for the commercial fisheries of Lake Michigan and Lake Superior. On February 4 and 6, 1936, representatives of the Province of Ontario and of the States fronting Lake Erie conferred at Washington, D. C., reaching the conclusion that control by an international commission governed by a treaty with Canada offers the only practicable means of saving the fisheries. A method of procedure to obtain this international control was adopted, but no concrete results have followed. At a conference held on March 16 and 17, 1936, at Toronto, Ontario, between the Province of Ontario and the State of Michigan, uniform regulations of the commercial fisheries of Lake Huron were discussed and a tentative agreement was reached regarding the size of mesh in gill nets used for chubs and the size limit of yellow perch. At all of these conferences the various representatives reached a common understanding on the need of uniform regulations on each of the Great Lakes and on the more important legislation that should be adopted. The various State legislatures, however, have consistently failed to enact into law the recommendations that have resulted from such conferences.

Grateful acknowledgment is made to the authorities of the University of Michigan for laboratory space provided and for many other courtesies extended to the staff at Ann Arbor.

FISHERY STATISTICS

The detailed analysis of commercial fishery statistics of the Great Lakes waters under the jurisdiction of the State of Michigan was continued through 1936. The most important items of progress were the completion of summaries for Lake Superior, 1929–34; the tabulation of basic data and the preparation of summaries for all areas, 1935; the completion of the study of the relationship between fishing time and size of lift; the development of more concise methods of measuring and expressing fluctuations in abundance and production of fish and in the intensity of the fishery; and the application of statistical data on the yellow pike-perch to the question of the effectiveness of artificial propagation of the species.

In Progress in Biological Inquiries, 1935, it was suggested that it might prove unnecessary to include a consideration of the fishing time of stationary gear in the preparation of statistical data for the estimation of fluctuations in abundance of commercial species in

Great Lakes waters. Continued study has supported this earlier suggestion. In a series of comparisons, no significant differences could be found between abundance curves prepared from data that ignored the time element and curves prepared from data that included consideration of fishing time. The knowledge that the consideration of fishing time need not enter in the computation of fluctuations in abundance has made possible a great simplification of statistical procedure.

Methods have been developed whereby fluctuations in the abundance and production of fish and in the intensity of the fishery may be expressed in terms of simple index numbers. These indexes of abundance, production, and fishing intensity are all computed with reference to average conditions over the 6-year period, 1929–34. A convenient feature of the method lies in the fact that the basic data for the different statistical districts can be combined readily by a simple process of summation.

Statistical data on the fluctuations in abundance and production of the yellow pike-perch have proved of great value in connection with problems concerning the effectiveness of artificial propagation of the species. For the past several years yellow pike-perch have been exceptionally plentiful in Saginaw Bay, the chief production center of the species in Michigan waters. Many fishermen believe this increase in abundance to be the result of the intensive artificial propagation that was begun in 1924. However, the fluctuations in abundance and production of yellow pike-perch in Saginaw Bay over the period 1929–35 showed no correlation with the variations in the numbers of fry planted in earlier years. Statistical data for other areas revealed that the abundance of pike-perch increased simultaneously throughout the State of Michigan waters of Lake Huron and Lake Michigan. Although no fry were planted in southern Lake Huron, southern Lake Michigan, nor Green Bay, the relative increase in the abundance of yellow pike-perch was as great in each of these areas as in Saginaw Bay. A report of this study appears in the 1936 Transactions of the American Fisheries Society.

PIKE-PERCHES OF LAKE ERIE

A manuscript entitled, "Morphometric and Life History Studies of the Pike-Perches (*Stizostedion*) of Lake Erie," was completed by Dr. H. J. Deason during 1936. Most of the conclusions of these studies have been presented in Progress in Biological Inquiries for 1933, 1934, and 1935. There are, however, two additional major conclusions, not previously reported. In order to determine the relation between age and growth rate and various characters and body proportions of the blue and yellow pike-perches, ages were determined from the scales of specimens employed for the taxonomic study. Within a single population the morphometric characters varied according to age and growth rate. The differences in age or rate of growth between the yellow and the blue pike-perch of Lake Erie, however, could be only partially responsible for the observed differences in the average values of certain morphometric characters. Because of the fact that the ranges of variation of the characters of the blue and yellow pike-perch overlap to a considerable extent, that the habitats are not mutually exclusive, and that individuals inter-

mediate in growth rate and character ratios occur, the designation of the blue pike-perch of Lake Erie as a distinct species (*Stizostedion glaucum* Hubbs) does not appear to be warranted. The blue pike-perch of Lake Erie has, therefore, been reduced to subspecific standing, *S. vitreum glaucum* Hubbs. The yellow pike-perch accordingly becomes the type subspecies, *S. vitreum vitreum* (Mitchill). The so-called blue pike-perch of Lake Ontario cannot, according to available information, be regarded as subspecifically identical with the Lake Erie form. Subsequent study may suggest the desirability of placing the Lake Ontario "blue" in a new, and as yet undescribed, subspecies.

Growth compensation was demonstrated for the Lake Erie pike-perches. Calculated lengths at the end of each year of life showed that the fish which were longest at the end of the first year of life were almost invariably the longest throughout life. But fish with larger growth increments during the first year of life had smaller growth increments during subsequent years of life, and vice versa.

FOOD STUDIES

During the course of the Lake Michigan chub-net investigation in the years 1930, 1931, and 1932, the stomachs of approximately 6,000 lake trout (*Cristivomer namaycush*) and lawyers (*Lota maculosa*) were preserved. These fish were captured in experimental gill nets of five mesh sizes. A qualitative and volumetric analysis of the stomach contents was partially completed during 1936. No conclusions can be drawn until the data have been tabulated and summarized but it appears that both trout and lawyers feed to a greater extent than popularly supposed upon small noncommercial species. The results of this investigation will provide pertinent information on the following controversial questions: To what extent does the lake trout depend upon the chubs (*Leucichthys* spp.) for food? Is the intensive commercial fishery for chubs detrimental to the more valuable lake trout fishery through the reduction of the potential food supply of the trout? Is the lawyer, a fish of little commercial value, a serious food competitor of the lake trout? In addition the stomach contents will yield valuable data on the distribution of the smaller species of fishes which cannot be captured, at least in appreciable numbers, by any commercial fishing gear now employed.

LAKE ERIE GILL NETS

Considerable progress has been made in the compilation of data on the selectivity of gill-net meshes with respect to the yellow perch and blue pike of Lake Erie. The experimental fishing was carried on from September 1927 to December 1928. The results of this investigation are of particular interest at the present time (February 1937) since they may be the deciding factors in the disputes now being waged on Lake Erie concerning the proper size mesh to be legalized for gill nets employed in the catching of yellow perch and blue pike.

The Great Lakes program continues to emphasize the practical phases of scientific research; i. e., the conservation of the fisheries. This has been made an urgent necessity by the fact that the more im-

portant species, such as the whitefish, yellow perch, and the several species of chubs, are following the trail of the Lake Erie cisco and are definitely on their way to commercial extinction.

SHELLFISH INVESTIGATIONS

DR. PAUL S. GALTSOFF, *in charge*

The shellfish investigations during the year 1936 consisted in the continuation and completion of several projects initiated during the preceding year for the improvement of methods of oyster culture and the protection of the oyster against various pests. This work included studies on the metabolism and fattening of the oyster; sex changes in oysters and clams; the biology and control of such parasites of the oyster as starfish, drills (*Urosalpinx*), and borers (*Thais*); and the effect of pulp-mill pollution on oysters. These investigations were carried out at the Bureau's stations and laboratories at Woods Hole, Mass.; Milford, Conn.; Washington, D. C.; Beaufort, N. C.; and Apalachicola, Fla. The laboratory at Olympia, Wash., was closed and all the work on the Pacific coast was discontinued in May, when the State Department of Fisheries found it impossible to continue its financial support of this work. Dr. A. E. Hopkins, in charge of the investigations at Olympia, Wash., was transferred to Apalachicola, Fla. An additional P. W. A. grant permitted the continuation of the studies of the effect of pulp-mill wastes on oysters in the York River, Va., which were begun in 1935. At the request of the War Department a detailed program was prepared for experimental and field studies of the effect of dredging operations on oysters in the vicinity of the Intercoastal Waterways in South Carolina. At the recommendation of the Bureau, the War Department appointed G. Robert Lunz, Jr., who worked according to plans prepared by Dr. Galtsoff and under his supervision.

PHYSIOLOGY AND CULTIVATION OF OYSTERS

The production of oysters of high nutritive value is at present the principal problem of oyster culture in the Northern States. Good oysters are characterized by the storage of a large amount of glycogen in their tissues and by the presence of sufficient quantities of metals, especially iron and copper which are essential for a balanced diet. In order to determine the seasonal fluctuations in the chemical composition of oysters kept under known natural conditions, a large amount of material collected in 1934 and 1935 was analyzed for iron, copper, manganese, and zinc by Dr. Galtsoff and Charles D. Weber.

The results of the analyses show considerable fluctuations in the amount of these metals. Thus, iron varied from 103 to 914 mg per kilo; copper, from 669 to 3,000 mg; manganese from 5.10 to 7.92 mg; and zinc from 4,130 to 13,700 mg per kilo of dry weight. There were noticeable seasonal changes in the metal contents, especially in the manganese which was consistently higher during the summer months, probably owing to the accumulation of this metal by the ovaries, which showed a much greater manganese content than other tissues. In the ripe specimens there was from 51 to 59.6 mg per kilo of manganese in the ovaries as compared with 4.4 and 4.6 mg in the testes;

the muscles, gills, and the rest of the tissues showed a manganese content varying from 5 to 38 mg per kilo. A study of the localization of other metals in various organs revealed the interesting fact that the gills and mantle accumulate much larger quantities of metals than other parts of the oyster. In one experiment the mantle and gills were found to contain respectively 22,000 and 19,400 mg of zinc per kilo as compared with 14,300 mg in the visceral mass, and only 1,590 in the muscles.

The possibility of increasing the iron content of the northern oyster which, as has been established by the work of Coulson, is lower in this metal than the oysters from the South Atlantic States, has been tested in the laboratory and in outdoor tanks at Milford. Oysters kept in the laboratory and fed various iron salts showed only very slight increase in iron content in spite of the fact that they easily ingested the suspended iron oxide particles. The experimental work at Milford was undertaken with the cooperation of the Department of Physiological Chemistry of Yale University, which granted laboratory facilities for the chemical analyses. Two large concrete outdoor tanks, in which the water could be changed by the tides whenever desirable, were selected in order to keep the oysters in as nearly natural a condition as possible. Iron in the form of rusty nails was added to one tank and the other kept normal as a control. Initial samples for iron analysis were taken of oyster meats and sea water before the addition of any iron, and thereafter samples were taken from each tank at regular intervals. The nails added to the tank became quite rusty but apparently the rust formed is insoluble in sea water for no increase in soluble iron could be detected in 6 weeks. The experiment is being continued with iron added in the form of copperas, a cheap technical iron salt, and the indications are that this method will be successful.

PROPAGATION OF OYSTERS

Problems of the propagation of oysters were studied at Woods Hole where Dr. Galtsoff began an experiment on sex reversal in adult oysters and at the Milford Laboratory where Dr. V. L. Loosanoff followed the development of gonads in adult oysters of Long Island Sound.

The problem of sex reversal in adult American oysters is little understood. An experiment was therefore undertaken in an attempt to determine the factors involved in this phenomenon. To avoid the possible effect of injury, the sex of 202 adult oysters was determined by stimulating spawning, examining the discharged material and obtaining a kymograph record of the spawning reaction. Each oyster was then marked by cutting a number in its shell. Early in September all the oysters thus treated were brought to Milford and placed in the experimental tanks in five groups: Females only; males only; males and females in the ratio 2 to 10; and two groups containing both sexes in equal proportions. The purpose of the experiment was to determine whether the association of individuals of different sexes is one of the factors involved in sex reversal, as has been claimed by some investigators.

For the study of gonad development samples of oysters were collected from Charles Island oyster beds at biweekly intervals throughout the year. After the completion of spawning, the gonad follicles of oysters begin to shrink very rapidly, at the end of August occupy-

ing approximately one-sixth of the space between the liver and the body wall, while in the prespawning period virtually all of this space is occupied by gonad tissue. The shrinkage of the gonad follicles continues through September, when the gonads, upon superficial examination, appear to be in a wintering state. A more detailed study, however, reveals that only by the end of October, when the water temperature is still about 15° C., is the shrinkage completed. Histological studies show that the follicles are few in number and small in size and are scattered in the form of small islands through the connective tissue between the body wall and the digestive gland. Most of the follicles are confined to the portion of connective tissue lying immediately behind the body wall, but a few are found near the liver. The gonads remain in this state until spring. The sexes are distinguishable throughout the winter for the female follicles, besides having indifferent cells, always possess a large number of small young oöcytes. The male gonads containing gonia and a few spermatocytes are characteristically different in appearance from the female gonads.

Although changes occur in oyster gonads during the winter, it cannot be stated that the gametogenetic activities of the oyster are entirely suspended until the following spring, because in March when the water temperatures of Long Island Sound are at or near the freezing point, a slight increase in the size of the follicles and in the number of cells can be noticed. During April and the early part of May the follicles in many cases shown some increase in size parallel with the increase in the number of sex cells. In the middle of May, when the water temperatures reach about 10° C., apparently ripe spermatozoa may be found in some males. From this date on, very rapid changes occur. Simultaneously with the marked increase in gametogenetic activities, the follicles begin to proliferate and expand in all directions, but largely toward the liver. During the first week of June (water temperature 14°–15° C.) the expansion of the gonad follicles is so rapid that in a few days almost the entire space available for the gonad tissue is occupied, and the gonad follicles extend from the body wall to the boundaries of the digestive gland. The production of spermatozoa and ova enters its final stage and in a few weeks spawning follows.

BIOLOGY OF THE HARD CLAM

In an investigation of the life history of the hard clam, or quahog (*Venus mercenaria*), Dr. Loosanoff found that young clams possess distinctly bisexual gonads with a very strong predominance of males. A special study was therefore made of the sexual phases and development of the gonads of this mollusk. Observations showed that hard clams spawn in the laboratory at temperatures ranging from 23° to 30.2° C., the largest number of males spawning at 25°–26° C., while the females require a higher temperature of 29° C.

OYSTER PESTS

Biology and control of starfish.—The work on starfish was continued at the Milford Laboratory and in Long Island Sound by Dr. Loosanoff with the assistance of Dr. Robert Burrows.

Results obtained during three extensive surveys of the entire Long Island Sound in 1935 had indicated that the relative density of the starfish population at different depths and in different areas remains the same throughout the year. Therefore, it was quite apparent that no general migration of starfish occurs at any particular time during the annual cycle. To obtain further evidence on this problem, however, systematic observations were made on the starfish population of a specific area. Twenty sampling stations were established in the region between Stratford Point and Welch's Point. These stations were arranged in four rows of five stations each, corresponding to four selected depths of 10, 20, 30, and 40 feet. Observations were made once or twice a month throughout the year.

Analysis of data thus obtained indicates the stability of the starfish population over the 20-square-mile area under observation. Of the 13 surveys made, 9 showed the largest number of animals at the 20-foot level, 2 at the 30-foot, and 2 at the 40-foot levels. Predominance of starfish at certain depths cannot be correlated with any seasonal changes. On two occasions at different seasons of the year they were found more abundant at the 40-foot level than at other depths, once in March and once in the middle of July. Starfish were never found in predominating numbers at the 10-foot level. This significant fact disproves the idea that normally a regular inshore migration occurs during the prespawning time. In general, the observations in the chosen area corroborate the conclusions reached during the three extensive surveys of the entire Long Island Sound; namely, that the starfish are usually most numerous at the 20-foot depth, and that there is no definite inshore or offshore migration during different seasons of the year.

In addition to the regular surveys, a new method of studying the movements of the starfish population by releasing large numbers of stained animals was applied. It has been found that specimens dipped for a minute in a 1 percent solution of nile-blue sulphate acquire a distinct blue color which is retained for more than 9 months. In November 1935, about 12,000 stained starfish were liberated on an oyster bed in approximately 15 feet of water. Arrangements were made with local oystermen to report the finding of every blue starfish with the date and exact location of recovery. By the end of August 1936, the Bureau and the oystermen, chiefly the Connecticut Oyster Farms Co., had recovered 287 blue starfish.

Reports show that the farthest distance traveled by any of the animals was approximately 5,000 feet, or less than 1 nautical mile, and that they have a tendency to stay in more or less the same depth of water, apparently preferring 15 to 25 feet. As disclosed by these observations the movements of the starfish take place in all directions and appear to be irregular and reversible. The speed of migration is probably controlled by the abundance or scarcity of food, being more rapid when food is scarce.

These and previous studies indicate that starfish distribution is correlated with the presence of food. Starfish show no apparent preference for any particular species of mollusks, but seem to be equally satisfied with oysters, any of several species of clams, mussels, or other mollusks. The inequality of the starfish populations of the eastern and western parts of the Sound is immediately comprehen-

sible if the abundance or lack of food supply of these two areas is taken into consideration, for only those areas of bottom which contain living mollusks or their shells are suitable for starfish. Dead shells, while not contributing directly to the starfish food supply, provide favorable conditions for attachment, growth, and multiplication of many low forms of marine animals which constitute an important part of the diet of young starfish.

Spawning of starfish in Long Island Sound begins about the end of June when the temperature of the water approaches 20° C. and continues until the latter part of August. The free-swimming period lasts 3 weeks, after which the starfish larva sets on the bottom and undergoes metamorphosis. As very little was known of the setting of starfish in the Sound, a study of this problem undertaken in 1935 was continued in 1936. Results of this study may be summarized as follows:

1. In both years setting occurred at all depths ranging from mean low-water mark to 70 feet.

2. In 1935 the most intense setting occurred at a depth of 10 feet, whereas in 1936 the setting star-fish were more or less evenly distributed between 5 and 25 feet.

3. Setting continued from July 15, to September 9, 1935, and from July 27, until September 3, 1936. The most intense setting occurred on or about August 5, 1935, and on July 27, 1936. The survival of young starfish depends largely on their environmental conditions. Those that set on soft bottom usually die from lack of food. A hard bottom covered with dead shells offers more favorable growing conditions.

These studies of the distribution, movements, and propagation of starfish provide much needed information on which to base methods of control and eradication of the pest. It is evident that, inasmuch as there is no general well-defined seasonal migration of starfish, their movements usually originate from the areas of highest concentration. These dispersal centers are found in the western part of the Sound and in some places along the Connecticut shore. Such large congregations of starfish should also be considered centers of starfish propagation as the spawn produced by adult animals is probably carried by currents for a considerable distance. Larvae developed from the eggs discharged by starfish set on new oyster grounds and after transforming into starfish begin to attack young oysters and other mollusks. The elimination of such centers will materially reduce the starfish in Long Island Sound.

It is evident that the eradication of starfish cannot be very efficiently carried on as long as oystermen protect only their own grounds, for numerous unleased and uncultivated areas of bottom will then continue to serve as centers of starfish propagation and dispersal. The only effective method is to combine the efforts of individual oystermen in an attack on the areas of highest concentration.

During the summer of 1936, studies were continued on *Orchitophyra stellarum* Cépède, a gonad parasite of the starfish *Asterias forbesi*. Although this parasite is found generally in males, it occurs occasionally in females. Of 326 males examined microscopically, 43, or 13.2 percent, contained *Orchitophyra*, whereas only 5, or 1.1 percent of the 382 females were parasitized. The incidence of parasitism in

this species is much lower than that found by Smith in *A. vulgaris* and much higher than that found by Cépède in *A. rubens*. In Long Island Sound the percentage of parasitized males varies according to the locality, being as high as about 22 percent in the region of Stratford Point and as low as approximately 1 percent around New Haven.

The fact that no parasites were found in recently metamorphosed starfish taken from a region where parasitism is common, and the fact that infected larvae develop more slowly than normal ones, may indicate that all parasitized larvae die before metamorphosis and that the parasite does not remain quiescent until maturity. If such is the case, the method of parasitism in the adult starfish is yet to be discovered.

Experiments to determine the attraction of starfish to various foods and the factors that control their movements were undertaken by Dr. Loosanoff in the Milford Laboratory, using one of the large tide-refilling tanks containing about 10,000 gallons of water. In carrying out this work care was exercised to eliminate the effects of light, rapid changes in temperature, currents, and other factors which may direct the behavior of starfish. While the work has not been completed, the results obtained thus far can be summarized as follows: Starfish display but little preference for certain foods and because of poorly developed sense organs are unable to detect the presence of food until they come in contact with it. A preference for small mollusks rather than adults was evident.

Oyster drill studies.—Field studies of the drill population on representative tidal flat areas on the Eastern Shore region in Virginia carried out by Dr. H. F. Prytherch and William Hagen indicate that there are over 35,000,000 of these pests on the public oyster beds from Chincoteague to Cape Charles. On the private beds in Chincoteague Bay, where a considerable number of drills are removed each year by dredging and cleaning operations, there still remains a population of over 4,630,000 drills on approximately 4,000 acres of leased bottom, as judged by the results of experimental trapping operations. From the results of experiments on the rate of feeding of drills conducted under natural conditions in Bradfords Bay, in which medium-size drills were placed on areas planted with oysters of three different ages, it is estimated that the drill population on the Eastern Shore may destroy during one summer season approximately 500,000,000 seed and adult oysters. Records of 20 of the largest planters in Chincoteague Bay and vicinity show losses of marketable oysters ranging from 42 to 100 percent over a period of 3 to 20 months on beds where drills were abundant. On various public beds, located on the tidal flats, the destruction of adult oysters by drills ranged from 25 to 56 percent during the summer months.

A brief summary of methods of drill control was given in Progress in Biological Inquiries, 1935. A detailed outline of procedure for reducing the numbers of these pests on oyster bottoms along the Atlantic coast has since been given in a report entitled "Natural History and Methods of Controlling the Common Oyster Drills (*Urosalpinx cinerea* Say and *Eupleura caudata* Say)," which was prepared for publication during 1936.

Sporozoan parasite of the oyster.—Studies of the life cycle and method of distribution of a sporozoan parasite of the oyster, con-

ducted jointly by Dr. Prytherch and Dr. R. R. Kudo, show that part of the development of this micro-organism takes place in the intestine of the mud crabs, *Panopeus herbsti* and *Eurypanopeus depressus*, and part in the gills, muscle, mantle, and other tissues of the oyster. The mud crabs, which are abundant on oyster beds, feed on the infected tissues of dead oysters from which millions of spores of the parasite may be obtained. The developmental stages of the parasite in both of its hosts have been followed and the complete life history outlined. The sporozoan is apparently a new species of the genus *Porospora* and is similar to the form *Porospora portunidarum* found on the French coast which has an alternation of hosts between crabs of the genus *Portunus* and the mollusk *Cardium edule*.

Observations on the oyster borer, Thais.—Previous investigations have shown the destructiveness of the conch or borer, *Thais floridana*, to oysters; hence some means of control was sought by R. O. Smith at Apalachicola, Fla. The Louisiana method of trapping spawners on stakes appeared feasible; therefore on April 18, 1936, 75 stakes were planted on a selected part of a bar in St. Vincent Sound where large numbers of conchs were present. This method is based on the tendency of spawning females to climb before depositing egg capsules. Green gumwood poles, 2 to 3 inches in diameter and 12 feet long, were wrapped with fresh palmetto leaves from the bottom to the water line and firmly planted along the oyster bar in depths varying from 4 to 7 feet at low tide. It was found that the palmetto leaves served no purpose other than to expedite removal of conchs and egg capsules and the leaf wrappings were discontinued.

Capsules were first taken on May 25, the last previous examination having been made May 15. Bottom temperature on the bar on May 26 was 24.2° C. The stakes were increased to 120 and were lifted every other day, weather permitting. The average daily take of capsules was 100 in June, 200 in July, and 1,340 during the second week of August, after which spawning ended abruptly. In all, 20,000 capsules were removed from the stakes and destroyed. Observations on the correlation between salinity and deposition of capsules showed that a drop in salinity is regularly accompanied by reduction in number of capsules deposited.

In the laboratory 50 adult *Thais* were kept in a large tank for experiments and six were placed separately in battery jars, running sea water being supplied to all. The average number of eggs laid in a season by a full grown female of 8.0 cm (3⅛ inches) total length is approximately 200. The average number of eggs per capsule, as observed in capsules from five different females, was approximately 4,000 each. Total egg production per female per season is therefore around 800,000.

What is believed to be a chemotropism was discovered in sexually mature females. If capsules are placed in a jar with a mature female she will deposit her capsules next to them. If she lays more than once the second group is placed near the first, and in the mass experiment, only rarely were capsules scattered about the tank. The bulk of the spawning by all females was done in close proximity to other capsules and this was observed throughout the summer both in the field and in the laboratory. It has long been believed that the heavy deposition of capsules in one area is the result of a group mi-

gration to a definite spawning area. The observations made here, however, point to the theory of specific chemical attraction.

With an average temperature of 28° C. and salinity ranging from 25 to 35 parts per thousand, the eggs begin to hatch 20 days after the capsules are deposited. The length of the free-swimming period is unknown since efforts to keep the newly-hatched larvae in special jars have been unsuccessful.

Several experiments were made to determine the effect of decreasing salinities on survival of *Thais* embryos in capsules. It was found that the salinity could be dropped suddenly from 27 to 13 parts per thousand and allowed to remain there for several days without ill effect. A sudden drop from 27 to 4 parts per thousand kills all embryos within 20 minutes. However, if the salinity is lowered slowly, it may be reduced from 27 to 3 parts per thousand before mortality begins. These experiments were made at temperatures between 26° and 31° C.

No young *Thais* were taken in the field from the end of the spawning season until October 26, at which time the average length of those taken was 21.1 mm. On December 15 the average length was 26.9 mm. It is interesting to observe that the average length of young oysters eaten by young *Thais*, as of December 15, was 22.2 mm. Although young *Thais* prefer oysters they also consume mussels and barnacles.

AUTONARCOSIS IN THE OYSTER AND ITS INDUSTRIAL APPLICATION

It is well known that oysters in the shell can live out of water for several days, permitting their transplantation to selected growing areas or shipment to inland markets. Recent studies conducted by Dr. Prytherch, at the Beaufort laboratory, show that the ability of the oyster to survive outside of its natural environment is due to the fact that it puts itself into a state of suspended animation or narcosis soon after the shell is closed. In very young stages of *Ostrea virginica*, the functioning of many internal organs can be clearly seen through the transparent shell. Soon after shell closure there is complete cessation of heart action, blood circulation, ciliary movement, and a general inhibition of all metabolic activities, accompanied by a rapid increase in the hydrogen-ion concentration of the liquor.

Experiments have shown that the tissues of the oyster are narcotized by carbon dioxide generated principally by the gills, and that this condition is due primarily to the rapid development of a high carbon dioxide tension within the shell rather than to an increased hydrogen-ion concentration. Carbonic acid is particularly suitable for conserving the energy and prolonging the life of the oyster outside of its natural environment, as it readily penetrates and leaves the tissues without producing injury or the noticeable after-effects which result from most narcotizing substances.

In commercial operations approximately 60 percent of the oysters are shucked and washed before marketing. It was found that the meats are rarely killed by shucking and will survive washing in fresh water up to 3 minutes. If then placed in the usual airtight tin containers they will generate sufficient carbon dioxide to produce narcosis and reach the market alive and in as good condition as when shipped in the shell. Under these circumstances the oyster

liquor becomes a slightly acid medium in which the growth of bacteria and spoilage organisms is considerably retarded. A small amount of dry ice or gaseous carbon dioxide can be introduced into the containers if necessary to improve the keeping qualities of the meats during shipment.

HURRICANE DAMAGE TO OYSTER INDUSTRY ON THE EASTERN SHORE OF VIRGINIA

At the request of Congressman S. O. Bland a survey was made by Dr. Prytherch of the situation on the Eastern Shore of Virginia to determine the amount of destruction of shellfish by the hurricane of September 17, and the most practical procedure for rehabilitating the oyster industry of that section. In Chincoteague Bay and vicinity it was found that the crops of oysters and clams on private beds had been almost totally destroyed as a result of severe wave action and smothering by mud and sand. These losses, estimated at $125,000, were not only an immediate and serious misfortune for the planters during a particularly favorable marketing season but were also responsible for the closing of two large oyster-shucking plants which ordinarily provided employment for several hundred men during the winter months. It was found that 350 to 450 men in the Chincoteague region would be deprived of their customary employment because of hurricane damage to private and public shellfish producing areas.

In the vicinity of Hog Island and Willis Wharf the oysters were swept off most of the private beds and killed by "sanding" or by being buried under heavy deposits of mud and sand. The natural or public beds also suffered severe damage chiefly from the shifting of large volumes of soft mud from the tidal marshes which smothered the oysters with a thick layer of this material. In this region the labor situation was found to be less critical than at Chincoteague and involved creating employment for approximately 20 to 50 oystermen after the first of December.

OYSTER REEFS IN MOBILE BAY, ALA.

At the request of I. T. Quinn, State Commissioner of Conservation, and A. J. Bride, Chief Enforcement Officer of the Alabama Oyster Commission, the Bureau detailed James B. Engle, temporary assistant, to make a survey of the oyster bottoms in Mobile Bay with the view of assisting the State authorities in the rehabilitation of depleted oyster beds. After making a careful study of conditions on every oyster-producing reef in the bay, detailed recommendations were submitted to the Alabama Oyster Commission indicating the necessary amount of shell and seed oysters that should be planted on each reef. The recommendations also comprised more general suggestions for the preservation of the present reefs and specifically mentioned the dangers of using long-toothed dredges which cause serious damage to the reefs. Dredging with short-toothed dredges can be permitted on some of the hard and deeper reefs but only when it is necessary to thin out the very dense growth of oysters. Further recommendations include procuring of seed by the State; greater return of shells to the bottom; and a more liberal policy in leasing of the State-owned bottoms to private oyster growers.

OBSERVATIONS ON OYSTER BARS IN APALACHICOLA BAY, FLA.

During the year hydrographic surveys were made by R. O. Smith from January 16 to September 3, covering 45 stations in St. Vincent Sound, Apalachicola Bay, and St. George Sound. Nineteen of these stations are located on oyster bars. The surveys were undertaken with the view of obtaining a better understanding of the correlations between fluctuations in temperature, salinity, and turbidity of the water and the productivity of the oyster bars.

It has been found that most abundant setting occurs in the zone where large fluctuations in salinity occur, but that market oysters of the best quality are taken from areas of relatively high salinity. The northern ends of St. Vincent, Cat Point, Peanut Patch, and Bulkhead Bars, where salinity variations are greatest, are the most heavily populated but seldom produce oysters of large size, good shape, or desirable fatness of meats. On the other hand, Porters Bar in St. George Sound and bars in the western end of St. Vincent Sound are regularly fished out as they produce the best quality meats in this region.

In summarizing the condition of the bars in 1935 it was stated that unless additional areas can be brought into production, the present rate of fishing on producing bars will result in a steady decline in size and quality of the shell stock. This prediction has been realized during the present season, when the oysters were small (400 to 700 per gallon), and of poor quality. Planting of oysters and cultch is still urgently needed and adequate supplies of seed are available from Platform Bar.

OYSTER INVESTIGATIONS ON THE PACIFIC COAST

After 5 years of intensive investigation of the history of the native oyster of the Pacific coast at Olympia, Wash., by Dr. A. E. Hopkins, a report summarizing the significant results was prepared for publication and the work discontinued. The results of this work have already proven of definite value to the oyster growers and it is expected that they will be increasingly useful in the future. In the southern portion of Puget Sound where the average range of tide is 14 feet and the maximum range 20 feet, the grounds on which Olympia oysters are cultivated are located generally between the minus 2 foot and the plus 4 foot tide levels and are all exposed at extreme low tide. Most grounds are leveled and surrounded by dikes which retain a few inches of water over the oysters at low tide.

Market-sized Olympia oysters, which are hermaphroditic and viviparous, bear broods of 250,000 to 300,000 larvae. In general, the larger the oyster, the larger the number of larvae produced. Usually an oyster produces one brood each season, though in some years as many as 50 percent may bear second broods also. On the other hand, during some seasons only about 75 percent of adults bear broods.

Spawning of functional females begins in the spring when the minimum water temperature at high tide reaches 12.5° to 13° C. (critical temperature), and most broods are produced during a period of about 6 weeks at the beginning of the spawning season, although an occasional gravid individual may be found as late as October. An average period of 10 days is required for the larvae to develop within the maternal brood chamber from eggs of 100μ to 105μ in

diameter to active veliger larvae 180μ in length, at which stage they are discharged.

The free-swimming period of the larvae is 30 or more days, permitting wide dispersal and large mortality. It was found that mature larvae attach, or set, most frequently to the under side of horizontal surfaces, and as the angle of the surface departs from the horizontal fewer spat are caught. Several closely-connected bays were studied for the purpose of finding when the most profuse setting takes place. In all bays except one the typical setting season consists of two distinct periods, 6 to 8 weeks apart, which fall within periods of spring tides when tidal range is greatest. Secondary setting periods may occur between these two or after the second.

Further observations were made on the circulatory system of oysters following discovery of the "accessory hearts" which apparently pump blood from the excretory organs to the mantle. A description of these observations was published in a scientific journal.

A series of experiments on the effects of changes in salinity on the feeding activities of *O. gigas* was brought to a close and the results prepared for publication. Adaptation of the feeding mechanism to changes in salinity was studied by recording on the kymograph the degree of openness of the valves and the relative rate of flow of water pumped by the gills. Both the activity of the gills and that of the adductor muscle, which by controlling the position of the valves determines the size of the inhalant and exhalant apertures, are markedly affected by any considerable change in salinity. The initial effect of such change is to cause partial or complete contraction of the adductor muscle and slowing or cessation of the flow of water. Recovery, or adaptation, following a rise in salinity is very rapid as compared with adaptation following the same change in the opposite direction. The former may require a few hours, while several days may be necessary in the latter case.

Because of the great variability in activity of the gills and in degree of openness even under conditions of constant salinity and temperature, the results do not justify an exact statement of the optimum salinity. However, the optimum is probably not greatly different from that of ocean water, for salinities between about 25 and 39 parts per thousand appear to produce similar effects. The lower limit of tolerance, or the minimum salinity at which water is pumped effectively, is between 10.5 and 13 parts per thousand.

YORK RIVER INVESTIGATIONS

At Yorktown, Va., where a temporary laboratory has been established, work was carried forward throughout the year to determine the causes for the decline in quality and volume of production of oyster beds in the upper York River. Laboratory analyses and experiments were conducted by Dr. Walter A. Chipman, Jr., and Dr. Arthur D. Hasler under the direction of Dr. Galtsoff. The oyster-cultural aspects of the problem in the field were handled by James B. Engle. During the first few months of the year physiological experiments were also carried on by Dr. Nelson A. Wells. Laboratory assistance was furnished by Lloyd R. Garriss and Orlin K. Fletcher, Jr.

The decline of the York River oysters during the last 20 years has resulted in a serious loss to many depending upon this industry for a livelihood. Inasmuch as no similar changes in quality have been noted in the oysters of nearby rivers, it may be assumed that the decline of the York River oysters is the result of local conditions. To determine whether the complaints of oystermen were justified, healthy oysters were obtained from the James River and planted at seven stations in the York River for observation on the physical and chemical changes occurring. Oysters taken from areas of the York River where the oysters are poor were transplanted to other localities, and changes in their condition were carefully followed. The condition of the oysters found in the York River was observed throughout the year.

The oysters in the York River showed a gradation of condition. Those in the river below Claybank were healthy and marketable while those above that point were noticeably poor and unfit for market. The meats were watery and transparent and the majority of the oysters had spots of green on the body. The taste of these oysters was acrid and disagreeable. Food was found in the stomachs but apparently this material was not properly assimilated for the oysters had not fattened and were low in glycogen content. Shell growth was observed but there was no thickening and strengthening of the shell by calcareous material necessary for handling and shucking. The gonad development was slow and the spawning light.

The oysters taken from the Piankatank River, and used for comparison with those of the York River, presented an entirely different picture. These were healthy, showed a high glycogen content, and possessed strong shells.

Observations parallel to those made on the York River oysters were made on the James River experimental oysters planted in the York River. Those introduced into the lower river maintained a healthy growth, while those planted in the upper river became weakened and poor. Green spots appeared on the body and the meats became watery and emaciated. Four months after transplanting the healthy James River oysters to various sections of the York River they assayed almost the same percent of glycogen as the native oysters; i. e., the upper York planted oysters analyzed low and the lower York planted oysters analyzed high in glycogen.

A group of oysters was taken from a section of the York River where conditions were bad and transplanted to other waters. At the time of transplanting these oysters were unmarketable, being watery, emaciated, and containing spots of green material on their bodies. The shells were rotted and handling was almost impossible. In March 1936 several bushels of these oysters were transplanted to the lower York River and upper Piankatank River to see if replanting in an environment entirely apart from the harmful influence would better their condition. The results were very striking. The shells were improved, the meats "fattened," and the green disappeared. Eleven months after transplanting the glycogen content was double that of oysters remaining on the original beds.

One of the few remaining oyster planters of the York River transplanted oysters from the same area to a river several miles from the York. The transplanting was done in March 1936, and the oysters

were examined in September of the same year and found to be marketable. The meats were fat and filled the shell cavity and the shells were thickened by a deposit of white chalky nacre. Another planter replanted poor oysters from beds farther up the York River to the lower river and noted marked improvement. These examples offer conclusive proof that the upper York River environment contains harmful elements that are not found in the lower river and waters removed from the York.

Samples of oysters have been taken from various parts of the York River and from several places on the Piankatank River and examined by Dr. Galtsoff for the presence of the sporozoan parasite known to infest oyster tissues. The parasite was found in oysters from localities where conditions were good as well as from localities where they were poor, showing that infection with this sporozoan is not responsible for the poor quality of the upper York River oysters.

The relative spawning activities of the York and Piankatank River oysters can be judged by the abundance of free-swimming larvae and amount of setting when conditions are favorable. Examination of net plankton samples taken throughout the summer of 1936 disclosed zones of abundance or scarcity of the swimming stages. In general it can be said that the abundance decreases with the distance from the mouth of the river toward the head. In the lower York larvae were plentiful from the time the 1936 studies began in June until they ended in late October. The figures taken from counts of the net plankton samples arranged chronologically show two peaks of spawning, one in early July and the other in late September. The samples from the upper part of the river show a decidedly low count. The maximum of the upper-river spawning occurred during the last part of August and extended through the first week of September. An abrupt drop in average number of larvae per sample appeared in the vicinity of Purtan Bay and above. In the control river, the Piankatank, the same condition prevailed, spawning being heavier in the lower part of the river than in the upper. However, the differences between the upper and lower sections of the river were less marked than in the York River.

The setting of larvae followed the same line as the spawning figures with the lower part of the river receiving the heaviest set. There was an exception, however, in the York when a rather heavy set was recorded for the areas near and inside Purtan Bay. The set in the York River, except at station 20, was less than that noticed in the Piankatank River. The set was of commercial magnitude at several stations in the lower York and the lower-river station in the Piankatank.

A very complete program has been followed in obtaining a picture of the hydrographical conditions of the York and Piankatank Rivers through 1936. The examination of the water consisted of observations on temperature, salinity, pH, dissolved oxygen, phosphorous, turbidity, and net- and nanno-plankton content. Tidal cycles at Yorktown and at West Point were studied and the isohalines of the York and Piankatank Rivers were determined.

The percent saturation of the water with oxygen was found to be consistently low in the vicinity of West Point. A period of low oxygen occurred during the latter part of July at which time many

fish died in the river just below West Point. Tests made of the oxygen-consuming capacity of the waters showed a high value for areas below the pump mill at West Point. The effluent of this mill has many compounds which become oxidized readily in the river and thus tend to lower the dissolved oxygen of the water for a distance below the mill.

To determine whether or not there existed a normal plankton cycle in the York River biweekly samples were taken throughout the year and the quantity of available oyster food measured. A maximum plankton crop in the York River was observed at the usual vernal period, March to April. Slight increases were again noted in November and December. These fall increases did not exceed the spring maxima. Throughout the summer the amount of plankton remained comparatively low. There was a larger nanno-plankton crop in the upper York River than in the lower throughout the major part of the year. The average plankton in the York River appears to be normal and sufficient, and to constitute a greater amount of available food than is present in the Piankatank River where the oysters are, in general, fatter.

Since the chief source of pollution in the York River results from the effluent of a paper mill at West Point, studies were carried on testing the action of this polluting material on oysters and on oyster food.

Using the diatom *Nitzschia closterium* as a test organism for laboratory experiments in determining the effects of polluting materials from the pulp mill, tests were carried on at the Washington laboratory. The organisms were artificially cultured in a media of Miquel's solution and sea water. Pulp-mill effluent was diluted to various concentrations with the culture solution to determine the effect it had on the growth of this diatom. It was found that concentrations from 1:1,000 to 1:100,000 definitely stimulated growth. Concentrations greater than 1:500 inhibited growth. Concentrations less than 1:100,000 showed little or no stimulation when compared with control cultures.

In view of the fact that it is impossible for the oyster to feed during the time the shell is held closed, experiments were carried on testing the effect of pulp-mill effluent on the number of hours per day oysters were open. A total of 74 oysters were examined during the course of the experiment. Of this total, 50 oysters were exposed to concentrations of pulp-mill effluent in sea water ranging from 100 parts per thousand to 1 part in 10,000. Definite reductions in the number of hours the oysters were open occurred in concentrations down to 1 part of effluent in 5,000 parts of sea water. The results with weaker concentrations were less definite. This reduction occurred immediately after exposure in the stronger concentrations and after an exposure of 3 or 4 days in the weaker concentrations. A reduction in the number of hours open per day in a strength of 1 part in 10,000 occurred after an exposure of 23 days.

Using the carmine cone method developed by Dr. Galtsoff, experiments were carried on to determine the minimum dose of effluent that would cause a depression in the ciliary activity of oysters. Other studies were made using this method to test the recovery after treatment, tolerance, and sensitivity. The general results of 22 experi-

ments, in which 59 oysters were tested, showed a depression of ciliary activity in concentrations greater than 2.5 parts per thousand within 30 minutes after treatment was started. Concentrations below this were indefinite even after 24 hours of exposure. Full recovery of the ciliary activity did not return after treatment with 5 or 10 parts per thousand for 30 minutes.

Similar results were obtained by measuring the depression of ciliary activity by the drop-counting technique. Depression occurred in strengths greater than 2.5 parts of effluent per thousand parts of sea water.

Dr. Galtsoff's constant-level tank combined with the rubber apron method of Nelson (1935) was used for automatic simultaneous recording of the water output of experimental oysters subjected to pulp-mill effluent. Measurement of water filtration was made on 18 individuals, of which 7 were controls kept in unpolluted sea water and 11 were treated with various dilutions of pulp-mill effluent. Three oysters were treated with 5 parts per thousand of the effluent, 2 with 2.5 parts per thousand, and 5 with 1 part per thousand. Concentrations of 5 and 2.5 parts per thousand gave immediate and marked effects. The water output was depressed so that one oyster filtering 14.5 liters per hour for 2 days before treatment filtered 1 liter per hour during treatment with a solution of 5 parts per thousand. No recovery was evident the day after the treatment was stopped. Five oysters were treated with 1 part per thousand of pulp-mill effluent. Four out of the five responded with an altered behavior of muscle activity. Their water output was depressed within a week after treatment was started, e. g., the water output of one oyster was depressed 44 percent after 5 days of treatment, another 71 percent after 4 days. The controls remained unchanged in their rate of pumping.

It is important to note that under certain conditions of experiments in which the rate of filtration of water was reduced or stopped the shell of the oyster remained open and the shell closures were irregular. From this it would seem that the fact that the shell of the oyster is open and the adductor muscle shows activity does not necessarily indicate that the oyster is feeding.

Current measurements in the York River were carried on during the last few months of the year with the view of obtaining data which will allow calculation of the dilution of the pulp-mill effluent in the river. This activity will allow correlation of the laboratory findings with observations of conditions existing in the river.

All the evidence so far gathered indicates the existence in the upper part of the river of an environment decidedly harmful to oysters. Studies of the cycles of temperature, salinity, and plankton failed to demonstrate the existence of abnormal conditions which may be responsible for the pathological state of the oysters. On the contrary, the food supply in York River appears to be more abundant than in the Piankatank. On the other hand, direct evidence of the harmful effect of the pulp mill effluent is provided by the physiological experiments which prove the toxicity of the black liquor. Its deleterious action is manifested by its effect on the adductor muscle and on the complex pumping mechanism of the oyster. By decreasing the number of hours the oyster stays open the presence

of black liquor in the water cuts down the time normally used for feeding. The depression of the ciliary movement combined with the reduction in the periods of feeding results in the stunted growth of the oyster and its failure to accumulate reserve food material (glycogen). The experiments definitely show that the black liquor produces a general depressing effect inhibiting the principal functions of the organism.

AQUICULTURAL INVESTIGATIONS

DR. H. S. DAVIS, *in charge*

The increasing popularity of angling for sport and recreation has emphasized the urgent need of more information on the various factors which affect the development, growth, and well-being of our fresh-water game fishes. In view of the remarkable increase in the artificial propagation of trout and other game fishes during the past few years, it is surprising that so little attention has been paid to the life and activities of these fish after being liberated in natural waters. Yet the whole success of artificial stocking is dependent on a suitable environment and the ability of the fish to adjust themselves quickly to their new surroundings. For this reason special emphasis is being placed on field investigations to provide the basic information essential for the development of a comprehensive policy of scientific fish management.

TROUT CULTURE

Test waters.—The use of "test waters" in Vermont to obtain much needed information on the productive capacity of streams under intensive fishing and the best methods of maintaining maximum production was increased to the full extent allowed under the State law. These studies are under the direction of R. F. Lord, in charge of the Bureau's experimental hatchery at Pittsford, Vt., and were made possible by a law passed in 1935 by the Vermont State Legislature, authorizing the State Fish and Game Service to cooperate with the Bureau of Fisheries in collecting the desired information. Under the law a maximum of four test waters may be reserved for collecting angling statistics. The Bureau of Fisheries is to carry on the necessary stocking and field work while the State assumes responsibility for enforcing the regulations pertaining to test waters. Each angler must secure a special permit, issued without charge, and is required to report his daily catch on forms provided for the purpose.

Furnace Brook was the only stream operated as a test water in 1935, but in 1936 the program was expanded to include the South Branch of Middlebury River, and the West Branch of White River, both streams being representative trout waters. The selection of Chittenden Reservoir as a test water marks the first attempt in Vermont to obtain catch records from a lake.

The results from Furnace Brook are of special interest, since it is now possible to compare the total catch from this stream for two successive seasons. It is a clear-water stream about 25 feet in width throughout the test section, which includes about 4 miles of the upper reaches. A waterfall at the lower end acts as an effective barrier to prevent the ascent of fish from below the test section. Only brook

and rainbow trout are found above the falls. Furnace Brook is reputed to be one of the best trout streams in Rutland County, and being easily accessible, is very heavily fished.

During the 1935 season, 1,197 fishing reports were turned in, and during 1936, 1,107 reports were made. The total catch of legal trout was 8,589 in 1935 and 6,995 in 1936. Breaking down the reports by species we find that in 1935 the catch consisted of 5,645 brook trout and 2,942 rainbow trout; while in 1936 the catch of brook and rainbow was 4,371 and 2,624, respectively. The average catch per fishing effort was 7.2 trout in 1935 and 6.3 trout in 1936.

It will be noted that the decrease in the number of fish caught in 1936 as compared with 1935 was almost entirely due to a marked reduction in the number of brook trout, the decrease in the number of rainbows being too small to have significance. This result is even more remarkable in view of the fact that there has been no stocking of rainbows in Furnace Brook for several years, while large plants of brook trout, consisting of fingerling and yearling fish, have been made annually in September. It is evident, therefore, that not only are the rainbow trout in Furnace Brook self-sustaining, but they are able to maintain a fairly stable population without artificial aid even when subjected to intensive fishing.

Neither the South Branch of Middlebury River nor the West Branch of White River is as intensively fished as Furnace Brook and the total catch in these waters was much less. The average catch per fishing effort was 6.6 trout in the former stream and 4.6 trout in the latter. It is interesting to find that in Chittenden Reservoir the average catch per fishing effort was only 1.4 trout, but the fish were much larger than those taken in the streams, averaging about a pound in weight.

Collections of bottom samples in the three test streams during the summer of 1936 show an average of 1.167 grams of food organisms per square foot for Furnace Brook, 0.915 grams for South Branch of Middlebury River, and 0.732 grams for West Branch of White River. It is believed that these results are representative for mountain trout streams in this region.

Arrangements were completed with the United States Forest Service for the operation of four experimental streams in the White Mountain National Forest for the purpose of obtaining information on the relative value of trout of different sizes for stocking. The streams selected are Sabbaday, Downes, Oliverian, and Douglas Brooks, all tributaries of Swift River. These streams are very similar with respect to physical and chemical characteristics and abundance of food organisms. Each stream is to be stocked annually with brook trout of a certain size as follows: Unfed fry in Sabbaday Brook, 2-inch fingerlings in Douglas Brook, 4-inch fingerlings in Downes Brook, and yearling trout in Oliverian Brook. The Forest Service has assumed responsibility for obtaining a complete record of the numbers and sizes of trout taken from these streams each season, information that should be of great value in the development of plans for the proper management of streams in this region.

Big Levels Refuge.—Studies on trout streams in the Big Levels Refuge in the Natural Bridge Division of the George Washington National Forest in Virginia were continued under the direction of

E. W. Surber. Collections of bottom samples at several stations in St. Marys River and Kennedy Creek were made at monthly intervals, and data on all trout taken from these streams during the season were collected by the Forest Service. The primary purpose of the study is to obtain as complete information as possible on the results of artificial stocking.

Big Spring Creek, Va.—The trout production studies on Big Spring Creek near Leesburg, Va., were continued for the fourth consecutive year. The 1-mile section produced 30.2 pounds of trout per acre as compared with 29.7 in 1933, 27.7 in 1934, and 34.8 in 1935. Such uniformity in results over the 4-year period was unexpected and is the more remarkable because the stocking intensity was doubled in 1935, apparently without effect on production in 1936. It should be explained that trout grow very rapidly in this stream and practically all fish planted reach catchable size the following year.

Pisgah Forest project.—Through a cooperative agreement with the United States Forest Service arrangements have been made to utilize the streams of the Pisgah Division of the Pisgah National Forest, N. C., as an experimental and demonstration project of the value of scientific stream management as a means of improving angling conditions. The Forest Service has constructed a rearing station on the headwaters of the Davidson River which will be operated by the Bureau. In addition to rearing pools of various sizes, the station is provided with a residence, workshop, and laboratory. It is believed that this arrangement will provide an excellent opportunity for acquiring information essential to the development of a fish-management policy for streams of the southern Appalachian region.

Feeding experiments.—Owing to lack of funds, feeding experiments have been greatly curtailed during the past 3 or 4 years. However, several experiments were conducted at the Leetown hatchery with diets containing seal meal, salmon meal, preserved haddock, and "salmana." The chief interest in these diets centers around the use of seal meal because of its availability at low cost. This diet had previously given good results over a 3-month period but a duplicate experiment continued for a longer time resulted in heavy mortality, confirming results at other hatcheries where this product was fed for a considerable length of time.

Breeding experiments.—Fifty pairs of selected brook trout were mated at the Pittsford hatchery and the eggs incubated in individual lots. As usual, the better lots were reared separately through the summer. It is noticeable that the losses among selected fish from furunculosis have been decreasing each year and it is believed that a more resistant strain of trout is gradually being developed.

Similar experiments with brown and rainbow trout are being carried on at the Leetown hatchery.

Experiments with incubating eggs.—In an effort to determine the cause of the heavy losses suffered by brook trout eggs at the Leetown hatchery, duplicate lots of brook and rainbow eggs were incubated under varying conditions by E. W. Surber. Variations in the highly mineralized hatchery water were produced by adding very small quantities of iodine, by reducing the normal high free carbon dioxide

content and by lowering the temperature, which is normally about 54° F. Eggs were also incubated in aquaria supplied with circulating soft water.

The results were inconclusive and difficult to analyze, but apparently none of the variations in the normal water supply were particularly beneficial. Both brook and rainbow eggs in soft water high in oxygen gave the poorest results. Efforts to incubate brook trout eggs in brook water at lower temperatures failed on account of silt deposited on the eggs. On the whole, both eggs and fry in normal hatchery water did as well or better than the other experimental lots.

The failure to find any definite fault in the water supply indicates the desirability of investigations along other lines, and it is proposed to study the effect of environmental conditions and diet of brood stock on the developing eggs. That this may prove a fruitful field of research is indicated by the fact that eggs from hatchery trout that had lived several months in a large pond where they were dependent on natural food gave a much better hatch than the average.

California trout investigations.—Good progress was made during the year on the inland research projects of this unit. As noted previously, the work has proceeded along two major lines of effort; the Hot Creek brood stock experiments, and coastal stream steelhead studies. Personnel remained the same with Dr. P. R. Needham in charge of the field program, assisted by A. C. Taft. Two assistants, Leo Shapovalov and Leo Erkkila are assigned to the work by the California Division of Fish and Game as part of the joint cooperative program actively initiated in 1932.

Work at the Hot Creek station continued as planned and the first eggs were taken from the three select lots of fall-spawning rainbow on October 26, 1936. A total of over 800,000 rainbow eggs were taken, of which about 500,000 were eyed and hatched at Hot Creek. A considerable loss of both female and male adult brook rainbows was caused by furunculosis.

Experiments in rearing trout on natural food in ponds were continued for the fourth consecutive year at Hot Creek. This year only loch leven trout were planted in the four ponds available. The ponds were stocked in June and operated for approximately 3 months. An average survival of 72 percent was obtained, the best since these experiments were begun in 1932. In previous years' operation of the rearing ponds during the summer, the survival was only about 40 percent. The reason for the higher survival rate obtained in the summer of 1936 may lie in the fact that few predator birds fed in the ponds this season and but few of the large leeches, *Helobdella stagnalis*, abundant in the ponds in previous years, were present. The growth rate of the fish per month was about the same as that obtained in previous years, or approximately one-half inch per month.

Detailed records of anglers' catches were again taken during the open fishing season on Upper Angora and Convict Lakes. A series of gill-net sets were made in Upper Angora Lake after the fishing season had closed, to determine from samples of both marked and unmarked fish taken what age groups, species, and sizes of fish had survived. The complete data from catch records obtained over three fishing seasons are now being analyzed and prepared for publication.

Detailed plans were drawn up for the development of a major stream- and lake-management project on the Convict Creek drainage

basin in eastern California. This drainage basin contains over 12 lakes and 12 miles of stream lying at elevations from 7,000 to over 11,000 feet. It is proposed to place both the lakes and streams in this basin under a definite management plan concerned with stocking, returns from anglers, stream and lake improvements, and related matters. On the lower portion of Convict Creek an experimental stream, 4,000 feet in length and providing 33 sections divided by concrete flumes keyed for screens and flash boards, has been constructed in cooperation with the Forest Service. Experimental plantings of trout will be made here to determine the mortality of various sizes and species planted under varying environmental conditions.

At Scott and Waddell Creeks a census of the spawning runs is made each year in order to determine the basic facts in the life history of the steelhead and silver salmon and the return from known escapements. During the 1935–36 season the run and egg-take for steelhead at Scott Creek was the largest (882) in a number of years and, judging by the number of marked fish returning, was largely due to an unusually successful plant of yearlings during 1934–35. At Waddell Creek the run of steelhead was smaller than in 1934–35, but larger than during 1933–34. The run of silver salmon in both streams was considerably less than during the previous seasons. In the lagoon of Waddell Creek striped bass were found feeding on young trout and salmon during the height of the seaward migration of silver salmon and may possibly have had an influence on the diminished run of 1935–36.

A marked decrease was noted in size of the down-stream sculpin migrations passing through Waddell weir. If this decrease continues it seems likely that dams not high enough to bar the migration of steelhead and salmon could be installed in California streams to control the number of sculpins above such dams.

At both Waddell and Scott Creeks the losses due to furunculosis among adult steelhead and the young pondfish at Scott Creek were again heavy. Offspring from marked adult steelhead returning to Scott Creek were marked and planted in the stream in order to develop, if possible, a run of fish that would show resistance to this disease.

On the Klamath River 27,378 young steelhead were marked and planted in Beaver Creek during June. These fish were hatched from eggs obtained at Scott Creek. This is a continuation of the experiment to check, under somewhat different conditions, the results obtained at Waddell and Scott Creeks and to establish an annual run of marked fish which would give some indication of the varying intensity of fishing in the main Klamath River. King salmon to the number of 39,170 were marked and liberated in Fall Creek, another tributary of the Klamath, on August 15. On September 3 of the previous year 38,170 king salmon had been marked and liberated in the same stream.

As a part of the cooperation between the Forest Service and the Bureau of Fisheries, Dr. Needham assisted in a biological survey of the lakes of the Willamette National Forest in Oregon. Two biologists were employed for this work by the Forest Service, while the Bureau loaned most of the necessary field equipment and directed the work. A cooperative survey of High Sierra lakes for "check-dam" sites in the Sequoia National Forest in California was likewise carried out. Reports of both surveys have been presented to the agencies concerned.

POND-FISH CULTURE

Bass investigations.—In April 1936, experimental sections for the study of smallmouth black bass and associated fishes were established in two bass streams, the South Branch of the Potomac River near Romney, W. Va., and the Shenandoah River near Berryville, Va. Each section is approximately 4 miles long and the limits are plainly defined by appropriate signs. Anglers were requested to leave reports of each day's fishing in mail boxes set up at convenient points. These reports show that the average length of legal bass taken in the Shenandoah River was considerably greater than that of bass taken in the South Branch (13.3 and 11.9 inches respectively). Furthermore, the relative number of legal-sized bass was greater in the Shenandoah than in the South Branch (Shenandoah, 132 legal to 80 undersized; South Branch, 150 legal to 160 undersized).

The growth of the young bass was followed from the time the fry rose from the nests to the end of the growing season. It was found that in the Shenandoah, the larger stream, the bass reached an average length of about 4.25 inches at the end of the season, as compared with 2.75 inches in the South Branch. Other species of fish, including the stoneroller, common sucker, and fallfish, also grew more rapidly in the Shenandoah. The stonerollers, especially, grew too fast to be available as food for the average fingerling bass. The most desirable forage fish for fingerling bass appeared to be the blunt-nosed minnow, which had successive brooks of young throughout the summer and thus provided fish small enough for the young bass to consume. Minnows in general appeared to be less abundant in the South Branch, while bass were far more abundant per unit area. The hatch of fry on the 4-mile section of the South Branch was estimated to have been at least 216,000. This fact, among others, raises the question of the need for stocking a stream such as this with hatchery-reared fish.

Growth studies showed that very few bass in the South Branch reach the legal length of 10 inches before their fourth year while in the Shenandoah nearly all bass reached that length in their third year. This rapid growth of the Shenandoah bass was made in spite of the fact that the river carried large quantities of silt throughout the summer.

Quantitative bottom samples were taken at regular intervals in the riffles of both rivers. The average number and weight of bottom animals was somewhat greater in the Shenandoah and there was a marked difference in the characteristic organisms in the two streams.

Fingerling bass from the two streams also showed differences in the extent of parasitism. The livers of nearly all fingerlings from the South Branch showed encysted trematodes (Strigeidae) while Shenandoah fingerlings were nearly free from parasites. In some instances the parasitized livers were so large as to affect the external appearance of the fish.

Pond culture.—Early in the year O. Lloyd Meehean was transferred to the Marion (Ala.) station from Natchitoches, La., where he had been conducting investigations in pond culture for several years. Unfortunately, conditions at Marion were found to be unsuitable for such studies and they were discontinued at the end of the season. The results at Marion confirmed findings of previous

years that production of food organisms is greater in ponds containing vegetation than in those without an appreciable growth of higher plants. In the former the average weight of food organisms per square meter was 13.68 g while in the latter is was only 6.48 g. The presence of forage fish (sunfish) in the ponds was found to increase the survival of bass fingerlings 12.3 percent over that in the same kind of ponds without forage fish. The ponds at Marion are new and at a low stage of ecological development. Consequently, they are much less productive than ponds that have been in use for some time. Mr. Meehean estimates that it will require about 3 years to develop an adequate permanent fauna in these ponds.

FISH DISEASES

A hitherto unrecognized form of gill disease broke out in May among smallmouth bass in a rearing pond at the Leetown station and caused considerable mortality before its true nature was discovered. The losses occurred among brood fish and fry at about the time the latter were rising from the nest. The trouble was traced to an infection of the gills with a protozoan belonging to the Dendrosomidae, a family of Suctoria. This organism occurs on the gills in enormous numbers and appears as a somewhat elongated or rounded body closely attached to the surface of the lamellae. The parasites are about 30μ to 40μ in diameter and usually show a distinct orange color. In heavily-infested bass the outer ends of the gill filaments become enlarged and club-shaped. Later the swollen ends become necrotic and fungus develops, forming a mat of felted fibers to which cling particles of silt and debris, giving the appearance of a dirty white mass attached to the ends of the gill filaments. Eventually a considerable area may become necrotic, resulting in the death of the fish. Later in the season the same parasite was found on the gills of bass which were suffering a heavy mortality at a hatchery in Maryland.

Investigations of diseases among salmon and trout were conducted by Dr. Frederic F. Fish at the recently established pathological laboratory at Seattle, Wash. Experiments to determine the effect on fish of the use of disinfecting solution at regular intervals were conducted at the Birdsview, Wash., and Clackamas, Oreg., hatcheries. It was found that certain concentrations of disinfectants could be safely used on salmon and trout from egg to fingerling stages without risk of incurring any greater mortality than was encountered in the untreated control lots. In some instances the loss on treated lots was definitely lower than on the untreated lots although no specific disease was present. The maximum safe concentrations for weekly applications under the conditions at these hatcheries was found to be: Malachite green, 1:450,000; sodium dichromate, 1:125,000; chlorazene, 1:150,000. Potassium permanganate, even as dilute as 1:400,000, appeared to be distinctly toxic and the effect appeared to be cumulative.

After 12 months of experimentation, the impracticability of performing experimental work at routine hatcheries became so obvious that further work was dropped pending the construction of a small experimental hatchery that could be entirely devoted to this purpose. With the cooperation and financial assistance of the Division of Fish

Culture, an experimental hatchery is under construction at the Quilcene, Wash., station. This unit is expected to be in operation early in 1937 when the studies on disease prevention and control will be resumed.

The apparatus for prolonged dipping, which consisted primarily of a calibrated floating siphon, has been materially simplified. The modified type of apparatus has been in regular use at two hatcheries for the past 7 months and the hatchery personnel report it to be far more satisfactory than the earlier type. Both hatcheries have been applying malachite green in a 1:450,000 concentration to all fish and report definite success although accurate figures are not available.

During the months of May, June, and July, various hatcheries in the intermountain district were visited to observe the conditions and equipment and to confer with hatcherymen on their disease problems.

Experiments on the susceptibility of *B. salmonicida* to common hatchery disinfectants and to moist heat showed that a 1:10,000 solution of potassium permanganate will kill the bacteria in less than 10 minutes. With copper sulphate at the same concentration between 30 and 60 minutes were required to accomplish the same result. The most efficient disinfectant was "HTH" which, in a 1:100,000 solution, killed the bacteria in less than 10 minutes. The bacteria were found to show little resistance to moist heat, being killed in less than 1 minute at 54° C. On the basis of these experiments it is recommended that hatchery equipment be sterilized by placing in hot water at 55° C. or, in the absence of considerable organic material, in a 1:100,000 solution of "HTH" for 10 minutes.

Field studies on the occurrence of furunculosis among loch leven trout in Lake Madison, Mont., were undertaken during November and December. Cultures were made from the kidneys of adult fish by Dr. C. J. D. Brown of Montana State College and forwarded to Seattle for identification. Of 77 cultures taken at the Lake Madison traps four were found to contain *B. salmonicida*. This indicates that furunculosis was not as prevalent during 1936 as it was reported to be during the previous year.

The disease service has proved very popular and a large number of specimens submitted by various State and bureau hatcheries and by private individuals were examined at both the Washington, D. C., and Seattle laboratories. Although in most cases the service is necessarily limited to the examination and diagnosis of preserved specimens it has proved very helpful in enabling fish culturists to adopt proper control measures.

INVESTIGATIONS IN INTERIOR WATERS

Dr. M. M. Ellis, *in charge*

POLLUTION STUDIES

During the past year investigations concerning the toxicity of industrial effluents on aquatic life have been continued in 22 States so that to date some 60 major groups of effluents representing over 200 kinds of industrial wastes have been studied, assayed, and their components standardized. For many of these substances detoxifying procedures have been devised and tested. From these data on

effluents and soil constituents the manuscript for the second part of the pollution series studies, Trade Wastes, Chemical Effluents, and Natural Pollutants, has been prepared and will be submitted for publication during 1937.

One of the striking findings in the investigations of natural pollutants has been the high toxicity of minute quantities of selenium to fish, as little as 0.05 mg. of selenium being sufficient to produce a peculiar "pop-eye" condition in catfish after some 7 days. This condition was usually fatal in less than 3 weeks and was attended with marked edema and other pathological changes of the internal organs. This work on selenium is particularly significant in view of recent surveys which show this element to be a widespread menace in several Western States.

Several other substances also found in small quantities in some natural waters and soils, as boron, fluorides, titanium, etc., have also been found to present previously unrecognized hazards to fish and other aquatic life.

The investigations on fish physiology as related to water conditions have been greatly extended during the past year with the perfection of new apparatus for studying fish respiration, heart action, and internal metabolic activities.

MUSSEL PROPAGATION

During the summer of 1936 approximately 40 million fresh-water mussels, about equally divided between the yellow sand shell, *Lampsilis anodontoides*, and the river mucket, *Actinonaias carinata*, were planted at definite stations in northern Arkansas where the success of these stockings can be followed for the next 5 years. A good supply of brood stock for the river mucket has been located and during the spring of 1937 it is anticipated that the plantings listed above will be doubled.

At Fort Worth, Tex., the long-time experiments on mussels in confined areas have been continued with satisfactory returns. These tests have confirmed the previous findings that the river mucket is the most promising species studied thus far for commercial propagation, and have given additional information on the survival of fresh-water mussels under adverse conditions.

ICHTHYOLOGICAL INVESTIGATIONS

DEVELOPMENT AND RATE OF GROWTH OF FISHES

The study of a collection of young fishes from the South Atlantic States, principally from Beaufort, N. C., was continued by Dr. Samuel F. Hildebrand, assisted by Louella E. Cable. A manuscript devoted to the description of the development of 17 teleosts from the egg to the adult, as far as material was available, was prepared and submitted for publication. The rate of growth during the first year for some of the species is shown, and other life history notes and data are included.

SURVEY OF THE FRESH WATERS OF MISSISSIPPI

The general survey of fresh-water fishes in the State of Mississippi, undertaken by Dr. Hildebrand in 1933, was continued in cooperation

with the State Game and Fish Commission during July 1936, when various waters in the Delta section of the State were examined in regard to their natural characteristics, and were sampled for the fish population and fish foods present. Excessively hot weather and an extensive drought prior to the investigation had resulted in the death of many fishes in some of the very shallow overheated lakes. It is evident that many of the lakes in the Delta, which consist mostly of deep holes in the beds of rivers that have changed their courses, are gradually filling up as a result of erosion since the clearing of the land for agriculture.

FISHES OF THE CANAL ZONE AND PANAMA

The study of specimens and data collected by Dr. Hildebrand in Panama and the Canal Zone in 1935 in cooperation with the Gorgas Memorial Laboratory, Panama City, was continued. A manuscript dealing with the use of the Gatun Locks as a habitat and passageway for fishes was completed. The study of the general collection made in various places in Panama has revealed several undescribed species, and the preparation of descriptions and illustrations has beeen undertaken.

A general study of the American anchovies was undertaken with the view of producing order out of the chaotic condition of the present classification of this family of fishes. Studies of Atlantic coast specimens of both North and South America that were available in Washington, and of others borrowed for study from museums outside of Washington, have been carried almost to completion.

MARINE FISHES OF THE GULF COAST

Systematic studies of the fishes of the Gulf coast were continued by Isaac Ginsburg. Special attention was given to the families Pleuronectidae, Cyprinodontidae, and Syngnathidae.

INDEPENDENT ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORIES

WOODS HOLE, MASS.

Owing to lack of funds, the Woods Hole laboratory was not maintained on an operating basis in 1936. Although facilities were utilized in connection with the oyster investigations reported upon elsewhere, no independent activities were possible.

This condition not only retards progress in the Bureau's fishery investigations, but also represents the loss to the Bureau of advantages formerly gained from results obtained by independent investigators through use of the laboratory's facilities.

BEAUFORT, N. C.

Research.—The biological station at Beaufort, N. C., which was continued in operation during the entire year under the direction of Dr. H. F. Prytherch, provided facilities for the study of marine fishery problems of the South Atlantic region. The various investigations conducted here by the Bureau's staff, as reported in detail

elsewhere, dealt with the following problems: (1) The biology and control of the oyster drill, (2) the life cycle of a sporozoan parasite of the oyster, (3) autonarcosis in the oyster and its industrial application, (4) destruction of oysters by a hurricane on the Eastern Shore of Virginia, (5) spawning of the blue crab in North Carolina waters, and (6) reproduction and feeding of the commercial shrimp.

The Beaufort laboratory serves as headquarters for oyster investigations in the South Atlantic region and has cooperated with the conservation departments of the coastal States, the Works Progress Administration, and commercial fishing interests in the rehabilitation of public oyster beds, regulation of the clam and blue-crab fisheries, and continued advice to a cooperative fishermen's organization. At the request of the United States Engineer's Department an inspection was made of the field experiments and studies being conducted by them on the South Carolina coast to determine the possible damage to oysters by dredging operations in the Intracoastal Waterway. At meetings of the National Emergency Council in Raleigh and Durham, N. C., reports were presented describing the various activities conducted by the Beaufort laboratory for the conservation and development of the fish and shellfish resources of this State.

Laboratory facilities for marine research have been provided for 15 independent investigators from other institutions who were engaged in the following studies: Dr. H. V. Wilson, professor in the University of North Carolina, research begun at the laboratory the preceding summer dealing with the effects of certain narcotics on sponge syncytia; Dr. C. E. Tharaldsen, New York Homeopathic Medical College, the effect of cancer-producing substances on embryonic development of the sea urchin; Dr. Irene Bolich, Alabama College, influence of environmental conditions on cellular behavior; Greer J. Kimery, United States Department of Agriculture, process of decomposition in shrimp; J. Albert Fincher, University of North Carolina, early development and regeneration in the lower invertebrates; D. John O'Donnell, Illinois Natural History Survey, marine fauna of representative intertidal areas; Dr. Alan Boyden, Rutgers College, the blood relationship of animals; Gordon H. Tucker, University of North Carolina, regenerative powers of the cells of lower invertebrates; Dr. Hoyt S. Hopkins, New York University, effects of methylene blue on respiration and glycolysis in tissues of lamellibranchs; Dr. George E. Coghill, formerly of Wistar Institute, myogenic behavior in embryonic tissues of fishes; Dr. A. S. Pearse, Duke University, studies of the flatworm parasite of the oyster; George W. Wharton, Duke University, parasites of the intestinal tract of reptiles; Dr. R. H. Kudo, University of Illinois, sporozoan parasites of molluscs; Dr. E. Laurence Palmer, Cornell University, general natural history of seashore animals; Dr. Katherine V. Palmer, president of the Paleontological Research Institution, living and fossil molluscs.

Terrapin culture.—Artificial propagation of the diamond-back terrapin, conducted in cooperation with the Division of Fish Culture and under the immediate supervision of Charles Hatsel, yielded during the summer of 1936 a total hatch of 10,750 young terrapins. These were cared for and fed in the special rearing house for a period of approximately 2 months during the early fall after which they

were placed in the hibernating pens where they will remain until the following spring. Experiments are in progress to determine whether the young terrapins can be carried over the winter in the unheated rearing house by covering them with damp seaweed and maintaining a low even temperature by protection from direct sunlight. If this is possible it will eliminate considerable labor in transferring the young terrapins to and from the hibernating pens and will afford complete protection from rats and mice.

During May, 11,000 young terrapins of the 1935 brood which had been reared to an age of approximately 9 months were distributed throughout the coastal waters of the South Atlantic region as follows: Virginia, 3,000; North Carolina, 3,500; South Carolina, 3,000; and Georgia, 1,500. The actual planting of the young terrapins in brackish-water areas was carried out by the conservation departments of the several States and if continued and increased each year should help to maintain a supply of this valuable seafood. Progress is being made in the development of a cooperative program whereby the various States receiving terrapins will provide funds for continuing and increasing the artificial propagation of this species.

During the past 5 years the Beaufort laboratory has produced for distribution an average of 10,520 young terrapins per year. The cost of rearing these animals has ranged from 3½ to 5 cents per terrapin per year which includes the labor and expense of feeding the brood stock, repairing breeding pounds, collection and care of young, etc. Previous to 1931 the production of young terrapins over a 5-year period averaged approximately 5,000 animals per year. The reason for the increase since that time appears to be the purchase of additional brood stock during the spring of 1930, which included 540 adult females that began laying in 1931 and produced an increased yield of approximately 5,000 to 7,000 young per year. Previous terrapin-cultural experiments indicated that in general an average annual production of 12 eggs per female per year may be expected, a figure which is in agreement with results obtained in this work during the past 5 years.

The spawning of the blue crab.—At the request of the North Carolina Department of Conservation and members of the local crab industry, studies of the spawning of the blue crab were made at the Beaufort laboratory as a basis for regulation of the industry. The crab fishermen desired permission to catch and steam the female crabs which were carrying eggs or "sponge." A very high percentage of the crabs caught during the spring season were females, which the fishermen contended would spawn only once and die soon thereafter. Experiments conducted in laboratory tanks and outdoor pounds showed that each female crab developed and hatched 3 separate large batches of eggs during the period from May 26 to July 18. The period of hatching in each case ranged from 12 to 16 days. A short time after the third spawning all of the crabs died, apparently owing to termination of the life cycle after reproduction. The studies clearly indicate that protection of mature female crabs is advisable both before and after the first sponge is formed on the abdomen. Similar studies were undertaken in the late fall with crabs from winter dredging areas in Virginia, to determine what percentage of the crabs caught in this fishery are

mature females which will develop into sponge crabs during the following spring. This knowledge should be of practical use in future regulation of the crab industry, particularly during a period of scarcity when protection of potential spawners may be advisable.

APPROPRIATIONS

Funds for the work carried on by the Division of Scientific Inquiry in the calendar year 1936 were derived mainly from the appropriation, Inquiry Respecting Food Fishes, and approximately one-half of the appropriations for each of the fiscal years 1936 and 1937 was available for this work. The appropriation for the fiscal year 1936 was $164,700, an increase of 7½ percent over the preceding year. The appropriation for the fiscal year 1937 was $172,000 or a further increase of 4.4 percent over 1936. By means of these increases in appropriations it has been possible to reestablish several positions in the scientific field staff to take up investigations which had been discontinued previously because of repeated reductions in annual appropriations. A summary of the amounts available for the various major projects in each of the two fiscal years follows:

Project	1936	1937
Regular appropriations:		
Commercial fishery investigations	$109, 580	$113, 530
Oyster cultural investigations	15, 840	19, 200
Aquicultural investigations	34, 900	33, 845
Conserving fish by screens and ladders	2, 000	1, 550
Washington laboratory and administration	2, 380	3, 875
Total	164, 700	172, 000
Allotment for maintenance and operation of vessels	11, 400	26, 300
Special funds:		
York River pollution investigations	16, 740	17, 456
Bonneville fishway design	6, 564	----------
Shellfish pest control studies	100, 000	25, 000

In the fiscal year 1936 a special appropriation of $100,000 for shellfish investigations, available for use in the fiscal years 1935 and 1936 together with the subsequent appropriation of $25,000 for the same purpose for use in the fiscal year 1937, made possible the continuance of a large-scale survey of the distribution of shellfish pests and an investigation of the means of controlling them. An additional allotment of $10,000 was provided by the Public Works Administration for the continued investigation of the effects of pulp-mill wastes on oysters of the York River, Va. An increase in funds allotted for the operation of Atlantic coast vessels made possible extensive alterations and the recommissioning of the motor vessel *Pelican* for use in the shrimp investigations in the South Atlantic and Gulf coast regions.

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